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TIROS II METEOROLOGICAL SATELLITE SYSTEM

FINAL ENGINEERING REPORT

VOLUME I

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PREFACE

This is the Final Engineering Report for the TIROS II Meteorological Satellite System, which was developed by Astro-Electronics Division of the Radio Corporation of America for the National Aeronautics and Space Administration. The Report is issued in accordance with the requirements of NASA Contract No. NAS5-478.

This Report provides technical descriptions of the design improvements and the additions made to the TIROS satellites and ground stations in preparing them for use in the TIROS II Meteorological Program; describes the various system and subsystem tests, and the environmental tests; and describes the prelaunch and launch phase activities at the TIROS ground stations. The post-launch operations and an evaluation of the performance of the TIROS II satellite will be presented in a TIROS II Post-Launch Evaluation Report.

The background of the TIROS project is discussed in the "Final Comprehensive Technical Report, TIROS I Meteorological Satellite System." The "Post-Launch Evaluation Report" for the TIROS I Meteorological Satellite System contains detailed discussions of the evaluation results. These results led to the design improvements which were subsequently incorporated in the TIROS II satellites and ground stations.

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PART 1. INTRODUCTION

The TIROS II Meteorological Satellite System was the second in the series of TIROS programs. On November 23, 1960, the TIROS II satellite was launched and injected into a nearly circular orbit, having an apogee of 453 statute miles, a perigee of 387 statute miles, and a calculated eccentricity of 0.007.

The TIROS II program was commenced in May 1960 . During the comparatively short time schedule (May 1960 until the date of launch), it was RCA's task to: (1) make recommendations for design improvements based on the TIROS I evaluation program; (2) incorporate the significant design improvements into the TIROS II satellite system; (3) integrate the NASA IR experiment into the satellite and ground station equipment; (4) provide for attitude control of the TIROS satellite; (5) develop a means to minimize the increase in satellite weight resulting from the addition of the IR experiment; and (6) modify and regroup the ground station equipment, which had been installed Kaena Point, Hawaii, CDA station, so that it would be suitable for the split-site environment of the Pacific Missile Range.

Four satellites, three flight models and one prototype, were available for the TIROS II endeavor. The satellite design improvements and equipment additions were proven by extensive high-level (approximately three times the anticipated level of the launch and orbit environment) testing of the prototype satellite. The compatibility of the satellites and the TIROS II ground stations was also proven using the TIROS prototype satellite. The "proven" design changes and additions were incorporated in the flight model satellites.

Since the ability of the TIROS satellites to withstand an environment, which was even more severe than the actual launch and orbit environment, was proven by high-level testing of the prototype satellite, the test level for the flight model satellites was limited to the predicted flight-level environment. This basic test philosophy proved to be valid in that both the TIROS I and TIROS II satellites were successful.

The design modifications and additions to the satellite and ground stations, the various test phases, and the launch and orbit considerations are contained in the main body of this report. Data pertaining to the command frequencies, the programming sequences, and the tests performed to ensure successful orbital operation of the TIROS II satellite are contained in the Classified Supplement to this report.

Background data for the TIROS projects and detailed descriptions of the "unchanged" TIROS components are presented in the "Final Comprehensive Technical Report, TIROS I Meteorological Satellite System." Because of the frequent references to that report, it is referred to simply as the TIROS I Final Report. A description of the evaluation program and the evaluation results that led to the design improvements, which were incorporated into TIROS II, is presented in the "Post-Launch Evaluation Report" for the TIROS I Meteorological Satellite System.

PART 2. DEVELOPMENT AND DESIGN

SECTION I. LAUNCH AND ORBIT CONSIDERATIONS

A. INTRODUCTION

The TIROS II launch and orbit considerations included studies to:

(1) determine the attitude required to ensure reliable operation of the satellite's subsystems;

(2) determine the optimum time for launch;

(3) determine the attitude control sequences that would provide the optimum path for photocoverage;

(4) establish a basis for determining the operational sequence (remote or direct, TV system 1 or 2), the "start-time" of the sequence, and the duration of the sequence required to ensure complete photocoverage of a selected area; and

(5) develop video and communications traffic estimates.

Since the satellite-to-ground contract time has a direct affect on the selection of operational sequences and on traffic estimates, predictions of this contact-time were included as part of the launch and orbit considerations.

B. PREDICTED SPIN-AXIS PATH

The addition of the attitude control coil to the TIROS II satellite afforded a means of controlling the path of the satellite's spin axis. By use of this control, RCA proposed to ensure optimum operation of the satellite's subsystems by maintaining a favorable sun angle. After initial studies indicated that the sun angle would have to be held either between 20 and 35 degrees, or between 55 and 70 degrees*, RCA conducted detailed studies to determine the time at which attitude control would be required, as well as to determine the duration of the control sequences.

The attitude control program that resulted from the studies called for the first attitude control sequence to be commenced on the 14th day after launch. (No attitude control sequences were planned for the first two weeks in order to provide the opportunity for engineering personnel to compare the theoretical model with the observed behavior of the satellite's

*The upper and lower sun-angle limits were established to ensure optimum thermal performance and optimum operation of the TV and power supply subsystems. The 35- to 55-degree range of sun-angles was excluded from normal operation to prevent the IR sensors from being damaged by prolonged exposure to the sun.

spin axis.) It was planned that, on the 14th day, the current required to guide the spin axis to and along the optimum path for photocoverage would be programmed into the attitude control coil.

Between the 14th day and the 35th day in orbit, the picture quality was expected to improve steadily without any further need for attitude control sequences. After the 35th day, the satellite's cameras were expected to look nearly straight down at a well illuminated area on the earth's surface. It was anticipated that only slight variations in the planned attitude control program would be required to compensate for differences in the satellite's orbital attitude throughout the entire range of possible launch times.

The path of the satellite's spin axis was predicted for the earliest, the mean, and the latest launch times of the launch interval. The predicted path for each launch time included the following:

(1) declination versus right ascension of the spin axis, with time in days after the first normal point marked on the curve for significant dates (the optimum path of the spin axis and the path of the sun also are shown on the same sheet);

(2) percent of orbit in the sun, including angle between the spin axis and the vector to the sun and the minimum angle between the lower end of the spin axis and the local vertical at the satellite (called "minimum nadir angle");

(3) declination of the spin axis versus days from first normal point; and

(4) right ascension of the spin axis versus days from first normal point.

The equations used for predicting the path of the satellites spin-axis are presented in Appendix A. These equations were solved using the RCA 501 computer.

The predicted path of the spin axis for the mean launch time is shown in Figure 1. The position of the normal point of the injection orbit is approximately 21.5 degrees North declination, 288 degrees right ascension. This point is marked with an X, and is dated "zero." For the first 14 days, the spin axis moves North and North-Northwest with no controlled moment applied. A maximum negative moment is then applied by means of the attitude control coil to precess the spin axis rapidly Southward, bringing the sun angle very quickly from 64 degrees to 32 degrees, and the declination of the normal point from 33 degrees North to 11 degrees South.

After the 20th day in orbit, a small negative moment is applied. This moment is increased on the 45th day, causing the spin axis to pass rapidly through the undesirable sun-angle range of 35 to 55 degrees (the range in which the IR sensors "look" at the sun), while still following the optimum photographic path. This 45th day attitude control sequence results in a slow increase of the sun angle to 19 degrees and then a rapid increase to 63 degrees, while the nadir angle drops to zero and then rises to 12 degrees on the 53rd day. A small positive moment is applied in order to maintain the minimum nadir angle between zero and 12 degrees until the 70th day after launch. The maximum negative moment is applied for three days to decrease the sun angle rapidly from 65 to 33 degrees. After slow Southward motion for two days, the full negative moment is again commanded for three days (to the

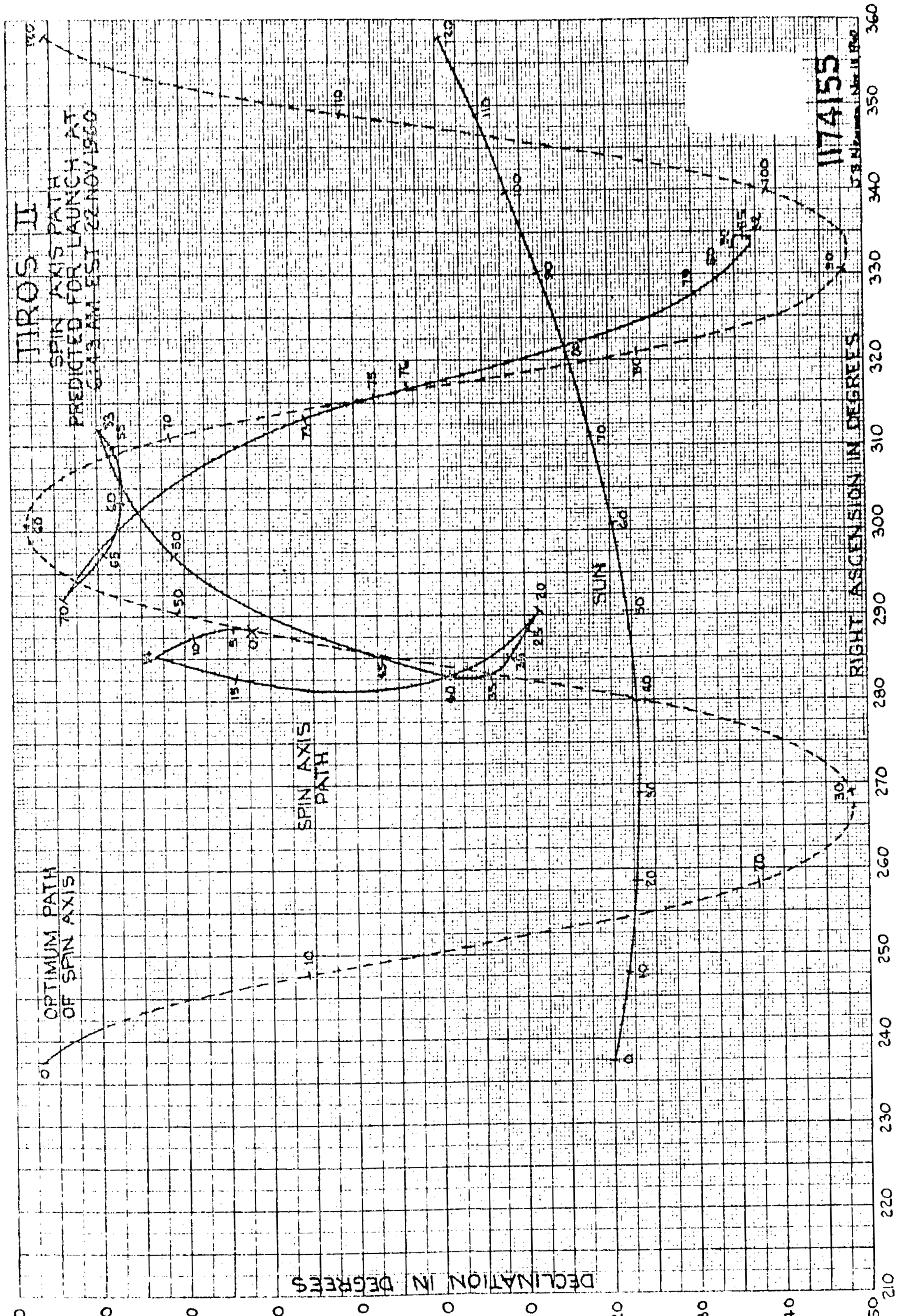

Figure 1. Predicted Path of the Spin Axis for Mean Time of Launch

79th day); during which time the sun angle decreases from 24 degrees to 5 degrees and then returns to 16 degrees. On the 79th day, the moment is decreased to a small negative value for three additional days, and then is turned off altogether through the 90th day. From the 82nd to 90th days, the minimum nadir value increases slowly to 13 degrees and the sun angle remains between 15 and 25 degrees.

Similar projections were made for the initial and final times of the launching period, and the results were plotted in the same way. In the case of the earliest launch time, the same attitude control sequences were followed with the exception that the torquing current which had been commanded on the 14th day, was changed on the 21st day rather than on the 20th day. In the case of the latest launch time the pattern was the same except that the attitude control sequence, which had been initiated on the 14th day, was terminated on the 19th day. The predicted spin-axis path for the earliest and latest launch times was similar to that predicted for the median launch time.

Figure 2[§] is a vector field graph for declination and difference in right ascension between the spin axis and the ascending node of the orbit. At each point, the line radiating from the point shows the inertial azimuth along which a positive impressed magnetic moment will cause the spin axis to move. Effects of differential gravity torque are not included. Therefore, the lines showing a direction of motion for the spin axis are valid only as approximate flowlines, and only for relatively large applied dipole moments. For small moments, differential gravity can cause drift transverse to the torquing direction indicated by the lines on the graph.

C. CALCULATION OF TIME OF LAUNCH

Time of launch is directly specified by $\Delta\phi$, the angle in right ascension from the normal point to the subsolar point, which in turn is directly dependent upon the location of the sun and the desired sun angle (α). Due to the presence of the I-R experiment, it was desirable to prevent a sun angle between 39 and 51 degrees. It was also desirable, due to power considerations, to keep the sun angle between 20 and 70 degrees. Since the normal point initially would be about a declination of 20 degrees north and the declination of the sun on the proposed date of launch (November 22, 1960) would be about 20 degrees south, a sun angle of less than 35 degrees could not be obtained. The initial sun angle was, therefore, chosen as 65 $\pm$5 degrees with the longitude of the spin axis east of the sun's longitude. This choice of orbit was made so that the sun angle would remain between 51 and 70 degrees for the first 14 days after launch without the aid of ground-station initiated attitude control sequences. For the values of the sun angle chosen, the time of launch had to be 1143Z $\pm$ 30 minutes or 6:43 A.M. EST $\pm$ 30 minutes.

Although the preceding values for declination, sun-angle, and etc. were computed using November 22, 1960 as the launch date, the effect of the one-day delay of launch was considered negligible. Therefore, the computed values were considered valid for the November 23, 1960 launch date.

§ This illustration is printed on a foldout page located at the rear of this Section.

D. CONTACT TIME BETWEEN THE SATELLITE AND GROUND STATIONS

The time available for contact between the orbiting TIROS II satellite and each CDA station was a vitally important system-design consideration. This contact time had to be of sufficient duration to allow the satellite to be programmed for remote operation, to playback recorded data, and to take TV pictures for direct transmission to the interrogating ground station.

The contact time per orbit and the number of orbits which could be contacted each day were functions of such orbital parameters as altitude, inclination, eccentricity, and longitude of ascending node; and of such ground station parameters as the latitude and longitude of the site, and the minimum antenna-elevation angle at which contact could be efficiently provided. To facilitate the determination of the contact time for a specific orbit, ground station "field-of-view" curves and a curve of the satellite's orbital trace over the rotating earth were plotted. The "field-of-view" curve defined the area within which the satellite could be contacted by the associated ground station. This curve, a small circle, was plotted on a Mercator map projection. The orbital trace was plotted on a tracing-paper overlay using the map grid for coordinates. This overlay was then calibrated either in degrees of true anomaly, or in minutes of flight time from the ascending node of the orbit. Figure 3[§] shows the "field-of-view" curves and elevation contours of each CDA station, as well as the orbital-trace limits within which the satellite could be contacted.

To determine the contact time, the orbital trace overlay was placed over the map containing the "field-of-view" curve, and the ascending node was aligned with the desired longitude. The contact time, or arc, was then read off as the distance between the intersections of the orbit trace with each field-of-view curve, and tabulated so that it could later be plotted against longitude. The ascending node was sequentially moved from one longitude to the next, with the contract time being tabulated at each longitude. This semi-graphical process was both fast and convenient for the circular orbit of the TIROS II satellite.

For the same basic orbit, the shape of the contact-time curves was a function of the latitude and the minimum antenna elevation of each ground station. If the location of a ground station is such that some of the satellite's passes are completely to the north of its field-of-view, the contact-time curve for that station is in the form of two separate humps as shown in Figure 4. As the station itself is moved Northward, the valley between the humps begins to fill-in and the humps move close together in longitude of ascending node. Finally, as the ground station location approaches and moves above the maximum latitude to which the satellite can travel (i.e., the inclination of the orbit), the contact-time curve is reduced to one hump and the area under the hump becomes less and less.

It must be noted that the period of usefulness of the PMR station overlaps with the useful period of the Fort Monmouth station. Such overlap could have been avoided by a different selection of ground station sites. A different selection of sites would also have increased the number of orbits which could have been contacted in any given day.

The number of orbits which could be contacted per day with the PMR-Fort Monmouth combination of stations was 8 to 9. The useful duration of these contacts averaged 9 to 10 minutes; this was ample time for direct, playback, and clock set functions whenever they

§ This illustration is printed on a foldout page located at the rear of this Section.

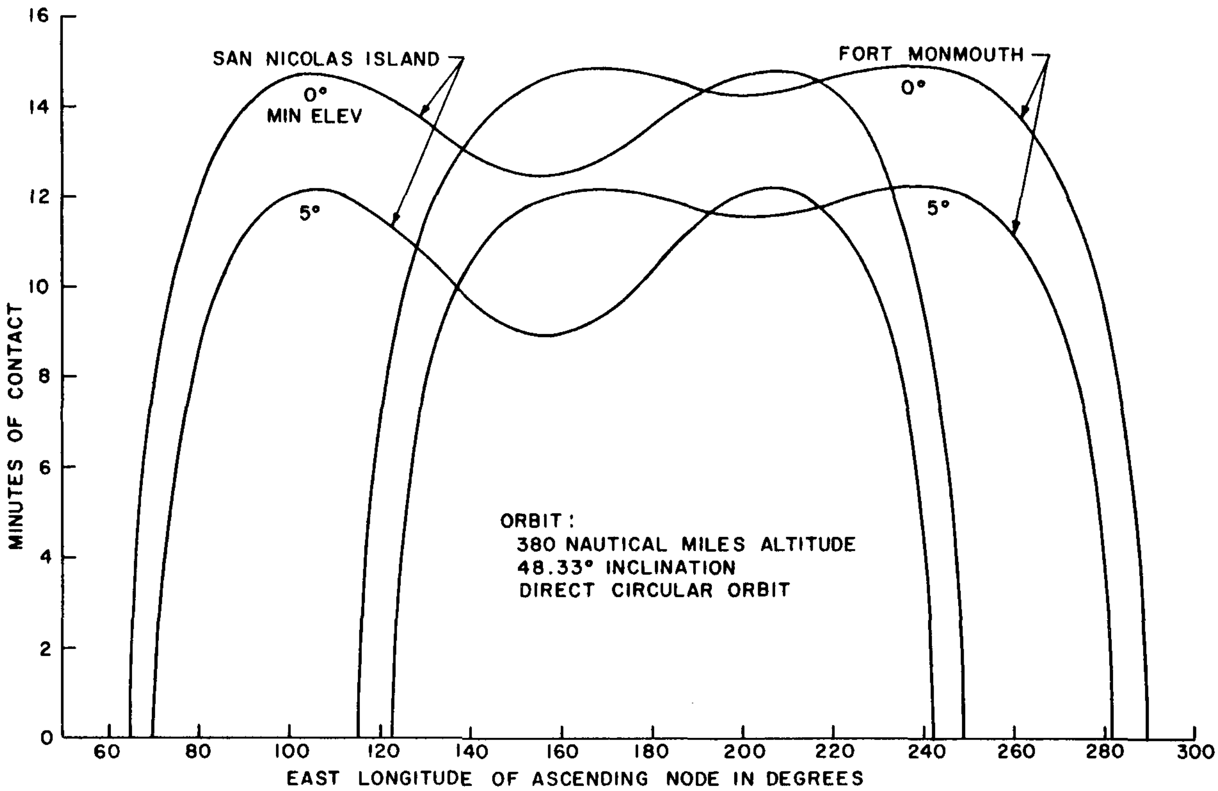

Figure 4. Satellite-to-Ground Contact Time

were required simultaneously. If the satellite system was limited in duty cycle due to insufficient solar input, programming could be reduced to the necessary level, if not, a generous contact capability was assured.

E. ACCESSIBILITY OF VARIOUS GROUND AREAS FOR REMOTE PICTURE-TAKING

One of the more interesting facets of the photocoverage prediction problem was the determination of the ground areas which would be seen by the satellite. The Mercator world map illustrated in Figure 3 also shows coverage zone boundaries. The nearly circular contours about each ground station show the minimum duration of contact which a satellite would have with that ground station if the subsatellite orbital trace passed tangent to or within the contour. Direct contact, (i.e., direct and immediate transmission to the ground station of TV pictures not stored within the satellite) was possible whenever the subsatellite point fell within the 0 minute contour. The typical subsatellite orbital trace as shown in Figure 3, was a sinewave-like curve centered on the equator. Its northbound crossing of the equator, called the ascending node, could occurr at any longitude. The zone boundaries shown as dashed lines are segments of orbital traces. (A similar but larger map and a movable clear orbit track overlay were furnished to each gorund station and TIROS Technical Center, and were used as prediction and programming tools).

The accessibility of ground area for photocoverage depended upon the number of passes that the satellite made over the area in question and the time that had elapsed since the satellite last passed over a ground station. The remote program delay clock in the satellite had a maximum delay of approximately 5 hours. Therefore, the beginning of remote coverage could be delayed up to 5 hours after the passage of the satellite over a ground station where the clock was set and started.

If the ascending node of an orbit occured at Longitude 280 degrees East (80 degrees West Longitude), that orbit would be the first of the daily sequence of orbits contacted by the ground stations. The Fort Monmouth ground station could program the cameras to take pictures somewhere on the orbit before the next ground contact. Remote pictures could be taken over the North Atlantic, Europe, etc., wherever illumination and attitude permitted, until the satellite re-entered the Fort Monmouth photocoverage circle.

For certain ascending node longitudes, the orbit would pass between the coverage circles without contacting either station. Therefore, remote pictures could not be taken once per orbit in the zones visible to the satellite along that part of its path, but rather once in the entire two (or more) orbit periods. This was defined as low availability for the direction noted. Thus, there was a much longer interval (4 or 5 orbits) between the last orbit contacted by the PMR station in each daily sequence of contacts and the first orbit contacted by Fort Monmouth on the following day. The clock could initiate the remote sequence only during the first 5 hours of this gap. Therefore, certain areas of the earth's surface were not available at all in a particular direction of travel. Two small areas, one near 49 degrees South Latitude at 200 degrees East Longitude (160 degrees West Longitude), could not be passed over by the satellite taking remote-mode pictures at any time. This loss of coverage was not a serious limitation, especially since the wide-angle camera often could see the horizon, up to 24 degrees of arc away from the subsatellite point. The orbit inclination and the distortion and illumination criteria, as already discussed, were the primary limitations to photgraphic coverage.

F. ACTUAL ORBIT ACHIEVED

The final objectives for the TIROS II orbit were: circular orbit; altitude 437.4 statute miles; inclination 48.33 degrees; payload verticality at 21.51 degrees North Latitude and 42.51 degrees East longitude (281.76 degrees right ascension) for launch at 1113Z (6:13 A.M. EST). The orbit finally achieved had an apogee altitude of 387 statute miles, perigee altitude of 453 statute miles, and an inclination of 48.53 degrees. The normal point was $25^{\circ} \pm 5^{\circ}$ North latitude and $45^{\circ} \pm 3^{\circ}$ East longitude ($283^{\circ} \pm 3^{\circ}$ right ascension) with launch at 1113Z (6:13 A.M. EST).

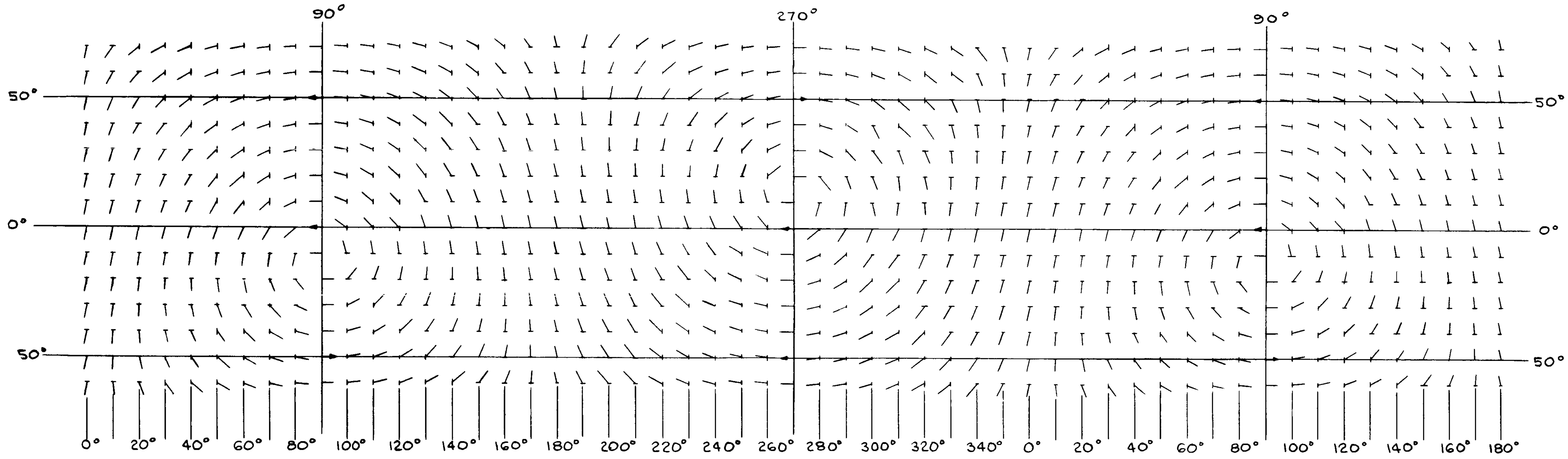

Figure 2. Vector Field Graph for Declination and Difference in Right Ascension between Spin Axis and Ascending Node of Orbit.

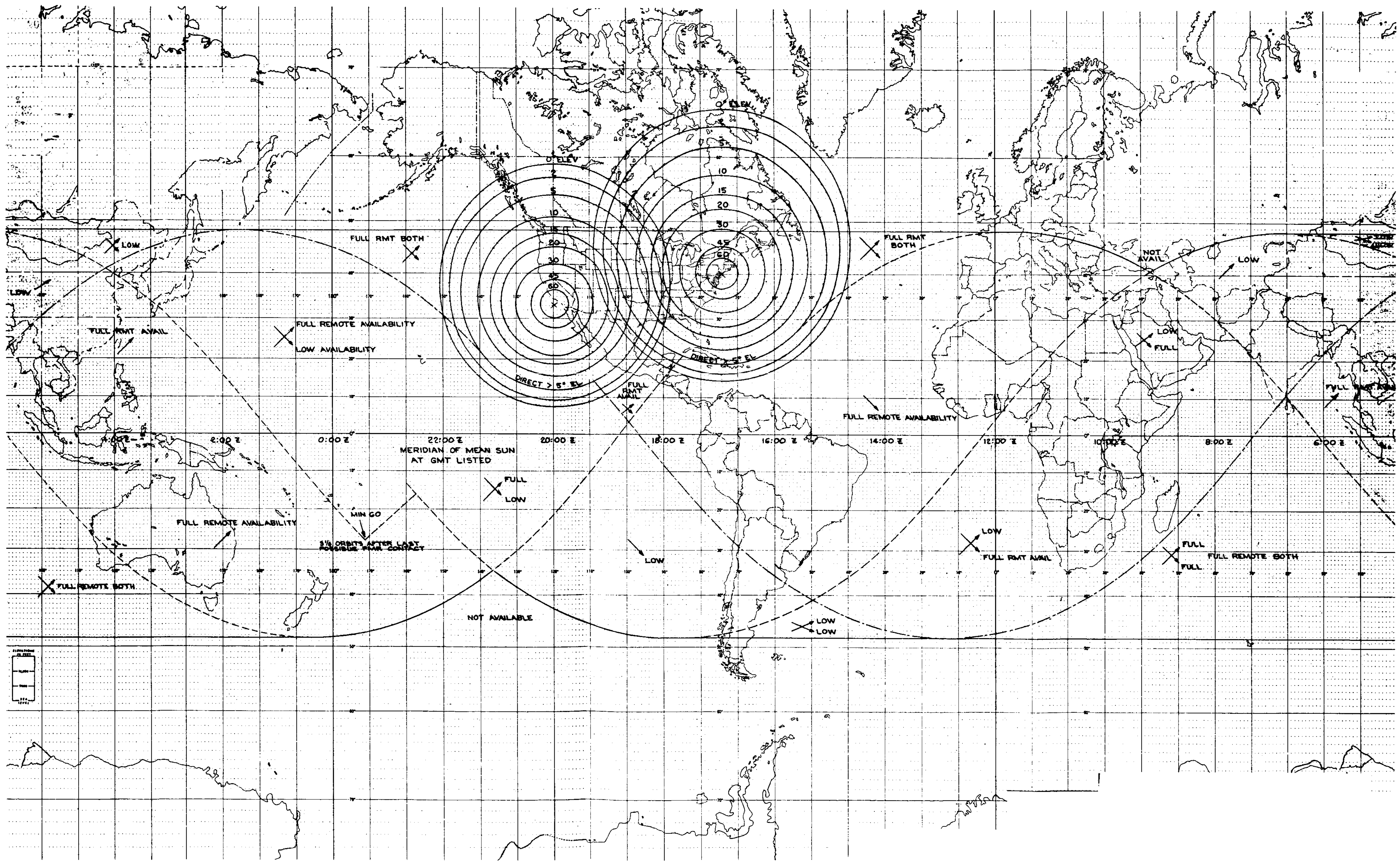

Figure 3. Ground Station "Field-of- View"

SECTION II. SATELLITE COMPONENTS

A. TV PICTURE SUBSYSTEM

The satellite-borne portion of the TV picture subsystem consisted of two separate picture channels; one for a wide-angle camera and one for a narrow-angle camera. Each channel consisted of a TV camera, a magnetic-tape recorder, a transmitter, and associated electronics. The system was capable of two modes of operation, direct and remote. In the direct mode of operation, the camera video information, in the form of frequency modulation on a subcarrier, was applied to the transmitter for direct sequential transmission to the interrogating ground station. In the remote mode of operation (used for picture taking while the satellite was not within communications range of a ground station) the camera video subcarrier was stored by the magnetic-tape recorder for later transmission to the ground station. Sun-angle data from the north indicator was also recorded and transmitted with the video signals. However, this data was recorded on a different channel of the recorder and was transmitted on a different subcarrier frequency.

The basic characteristics of the narrow-angle and wide-angle camera are as follows:

	Camera Channel	
	Wide Angle	Narrow Angle
Lens Angle	104^{o}	12.7^{o}
Lens Speed	f/1.5	f/1.8
Shutter Speed	1.5 milliseconds	1.5 milliseconds
Lines Per Frame	500	500
Vertical Sweep Duration	2 seconds	2 seconds
Video Bandwidth	62.5 kc	62.5 kc
Power Consumption (Average)	9 watts	9 watts

The development, the design, and the operation of the satellite-borne portion of the TV picture subsystem are described in Volume I of the TIROS I Final Report (Reference 1). The ground station components of the TV subsystem are described elsewhere in this report.

B. TELEMETRY AND TRACKING SUBSYSTEM

1. Introduction

The design objectives of the telemetry and tracking subsystem were : (1) to provide a 108-megacycle, continuous-wave, beacon signal from the satellite to aid in the acquisition and tracking of the satellite by stations of the TIROS ground complex; (2) to provide this signal redundantly from two beacon transmitters, thereby ensuring reliability of the system; and (3) to provide a method for telemetering satellite operational and temperature parameters redundantly via the beacon transmitters.

The TIROS II telemetry subsystem, although very similar to the TIROS I subsystem, contained certain modifications for improving the accuracy of the telemetered data, and certain additions for permitting transmission of attitude control data and for accommodating changes which were made in the horizon-scanner circuit.

The accuracy-improving modifications included locating temperature sensors directly on the satellite's electronic components, replacing certain of the TIROS I type sensors with expanded-scale sensors, and increasing the number of "calibration points" from two to six.

Additions included providing a means for reading out the position of the attitude control switch, and providing a means for applying the output of the horizon scanner directly to the beacon transmitter instead of first converting it to 3-kc bursts.

2. Functional Description

The telemetry and tracking subsystem provides two tracking beacons, one operating at 108.00 Mc and the other operating at 108.03 Mc. Upon command from a CDA station, these beacons are frequency-modulated with the data to be telemetered. This data, listed in Table 1, includes current and voltage levels at critical points within the satellite's electronic circuits, temperatures at significant locations within the satellite, and "calibration point" voltages.

Figure 5 is a functional diagram of the telemetry and tracking subsystem. Prior to separation of the satellite from its third-stage rocket, separation switch S4 is closed, applying a 2.5-volt d-c level to the subcarrier oscillator (SCO) section of beacon transmitter 2. This d-c level shifts the frequency of the SCO, nominally 1300 cps, to 1200 cps; in turn, the 1200-cps signal frequency-modulates the 108.03-Mc beacon signal which is being transmitted to the TIROS ground stations. When satellite separation takes place, switch S4 opens and the SCO output returns to 1300 cps, thereby indicating to the ground stations that separation has occurred.

As the satellite continues orbiting the earth, the analog outputs of the horizon scanner are applied to the SCO in each of the two beacon transmitters. These outputs cause deviations in the SCO frequency and thus cause frequency modulation of the beacon transmitters*.

When telemetry readout is commanded from the ground, switches S1A and S1B disconnect the horizon-scanner outputs from the two beacon transmitters and connect, in their place, the output of telemetry switch 1 to beacon transmitter 1 and the output of telemetry switch 2

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*The horizon-scanner outputs are also applied to the SCO's prior to separation, causing the output of one SCO to vary about 1300 cps and the output of the other to vary about 1200 cps.

to beacon transmitter 2. Each telemetry switch then proceeds to step through its 39 data sampling points before returning to its 40th or home position. As the switches step through the data sampling points the voltage at each point is momentarily applied to the associated beacon transmitter.

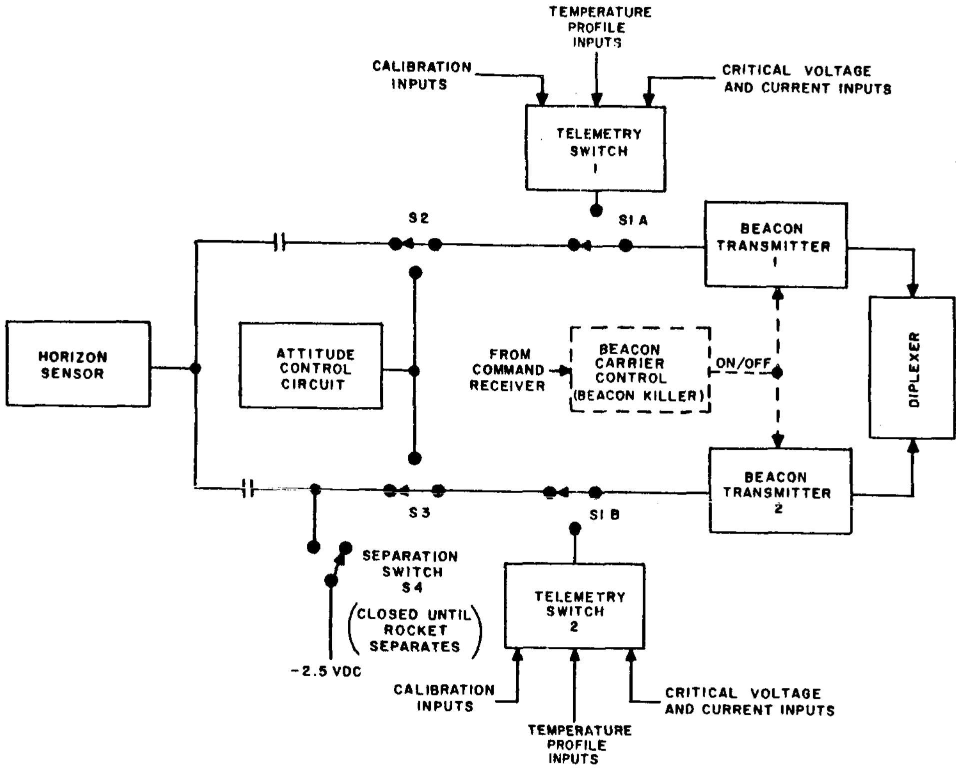


Figure 5. Telemetry and Tracking Subsystem, Functional Diagram

The voltage at each sampling point is between -2.5 volts d-c and +2.5 volts d-c; the level within these limits is indicative of the current, voltage, or temperature at the point. During the period in which a switch is sampling a specific data point, the voltage at the point causes a shift in the SCO frequency and thereby establishes a representative FM component on the associated beacon carrier.

The first six data points to be sampled by each switch (Table 1) are "calibration points." By comparing the response of the beacon transmitters and the telemetry recorders to these "calibration points," or known-voltage points, operator personnel are able to more accurately interpret the other telemetered parameters. After telemetry readout is complete, switches S1A and S1B again connect the horizon-scanner outputs to the two beacon transmitters.

The position of the attitude control switch, which is indicative of the amount and direction of current in the attitude control coil, can be read out and transmitted to ground at any time except during telemetry transmission. Read out and transmission of the position data is controlled from the interrogating CDA station. If the request for position data is

TABLE 1. TELEMETERED PARAMETERS OF THE TIROS II SATELLITE

Telemetry Switch Position No.	Parameter (108.00-Mc Beacon)	Parameter (108.03-Mc Beacon)
1	Calibration: Zero Volts	Calibration: Zero Volts
2	Calibration: -0.5 Volts	Calibration: -0.5 Volts
3	Calibration: -1.0 Volt	Calibration: -1.0 Volt
4	Calibration: -1.5 Volt	Calibration: -1.5 Volt
5	Calibration: -2.0 Volt	Calibration: -2.0 Volt
6	Calibration: -2.5 Volt	Calibration: -2.5 Volt
7	"X" String Battery Output: -28 Volts	"X" String Battery Output: -28 Volts
8	"Y" String Battery Output: -28 Volts	"Y" String Battery Output: -28 Volts
9	"Z" String Battery Output: -28 Volts	"Z" String Battery Output: -28 Volts
10	Main Load Buss: -28 Volts	Main Load Buss: -28 Volts
11	Regulated -24.5 Volts, System No. 1	Regulated -24.5 Volts, System No. 1
12	Regulated -24.5 Volts, System No. 2	Regulated -24.5 Volts, System No. 2
13	Regulated -13.0 Volts, System No. 1	Regulated -13.0 Volts, System No. 1
14	Regulated -13.0 Volts, System No. 2	Regulated -13.0 Volts, System No. 2
15	Vertical Sync Pulse, Clock No. 2	TV Xmttr Power Converters, Systems 1 and 2
16	Horizontal Sync Pulse, Clock No. 2	Temperature ‡, Base, at 130° location
17	Vertical Sync Pulse, Clock No. 1	TV Xmttrs Drive Voltage, Systems 1 and 2
18	Horizontal Sync Pulse, Clock No. 1	Temperature †, Base, at 130° location
19	Vidicon High Voltage, Systems 1 and 2	Vidicon High Voltage, Systems 1 and 2
20	Temperature ‡, Base, at 130° location	Temperature*, Base, at 210° location
21	Fil. and Focus Current, Vidicon No. 1	Fil. and Focus Current, Vidicon No. 1
22	Fil. and Focus Current, Vidicon No. 2	Fil. and Focus Current, Vidicon No. 2
23	"Home" Position of Rocket Switch	"Home" Position of Rocket Switch
24	Temperature*, Inner Top Skin at 3" radius	Solar Cell Array Output Voltage
25	Temperature*, Inner Top Skin at 12" radius	Temperature ‡, TV camera No. 2
26	Solar Cell Array Output Voltage	Temperature ‡, TV Xmttr No. 1
27	Temperature †, Base, at 130° location	Temperature ‡, Beacon Xmttr No. 2
28	500 cps Converter for Tape Recorder No. 1	500 cps Converter for Tape Recorder No. 1
29	500 cps Converter for Tape Recorder No. 2	500 cps Converter for Tape Recorder No. 2
30	Temperature*, Side Panel No. 2	Temperature ‡, Clock No. 2
31	Temperature*, Solar Cells at 3" radius	Temperature ‡, Battery Package
32	TV Xmttr Power Converters, Systems 1 and 2	Vertical Sync Pulse, Clock No. 2
33	Temperature*, Base, at 130° location	Horizontal Sync Pulse, Clock No. 2
34	TV Xmttrs Drive Voltage, Systems 1 and 2	Vertical Sync Pulse, Clock No. 1
35	Temperature ‡, TV Camera No. 2	Horizontal Sync Pulse, Clock No. 1
36	Temperature ‡, TV Xmttr No. 1	Temperature*, Inner Top Skin, at 3" radius
37	Temperature ‡, Beacon Xmttr No. 2	Temperature*, Inner Top Skin, at 12" radius
38	Temperature ‡, Clock No. 2	Temperature*, Side Panel No. 2
39	Temperature ‡, Battery Package	Temperature*, Solar Cells, at 3" radius
40	"Home" Position	"Home" Position

* Temperature Sensor Range: -30 to +100 degrees centigrade
‡ Temperature Sensor Range: +10 to +40 degrees centigrade
† Temperature Sensor Range: -20 to +10 degrees centigrade

made while camera system 1 is in use, switch S2 will close and the data will be transmitted via beacon transmitter 1; if camera system 2 is in use when the request is made, switch S3 will close and the data will be transmitted via beacon transmitter 2. Only one transmitter is used for sending the position data to the CDA station; thus the second channel is free to transmit horizon-scanner data.

A beacon control circuit, located within the satellite, permits the beacon transmitters to be turned off either when the satellite reaches the end of its operational life or when it is desired to conserve battery power. This "beacon-killer" operation is achieved when the satellite receives a start-clock pulse for a given period of time. The beacon carrier control circuit will turn the beacon transmitters "on" again if a "playback" or "direct-camera" signal is received by the satellite for a specified interval.

3. Telemetry Sensors

a. General

The temperature profile of the orbiting TIROS II satellite was obtained through use of both wide-range and expanded-scale sensors. The expanded-scale sensors, which were developed after the TIROS I evaluation program indicated the need for greater accuracy in telemetered temperature data, were of two types. One type was designed for linear operation in the -20 to +10 degrees centigrade range, while the second type provided linear outputs in the +10 to +40 degrees centigrade range. Both types of expanded-scale sensors had output scale factors of 12 degrees per volt.

The wide-range sensors were the same as those employed on the TIROS I Meteorological Satellite. They provided linear outputs within the -30 to +100 degrees centigrade range, and had an output sensitivity of 52 degrees per volt. The development of the wide-range sensors is described in Volume I of the TIROS I Final Report (Reference 1).

The location, type, and basic parameters of the twelve temperature sensors used in the TIROS II satellite are listed in Table 2.

b. Development of Expanded-Scale Sensors

The development of the expanded-scale sensors was aided by the knowledge that was obtained during the development of the wide-range sensors. It was determined during TIROS I that the sintered nickel-manganese semiconductors, which were to be used as the temperature sensors, displayed expodential conductance-temperature relationships. As one of the initial steps in the development of the expanded-scale sensors, a simple circuit was investigated to determine the feasibility of critically biasing the sensor so that it would operate within a selected, linear, portion of its temperature response curve.

The family of curves for the simple circuit is shown in Figure 6. The equation from which these curves were plotted is as follows:

$$e_o = \frac{RV}{R + R_t}$$

$$\frac{de_o}{dR_t} = - \frac{RV}{(R + R_t)^2}$$

Also,

$$\alpha = \frac{1}{R_o} \frac{dR_o}{dT}$$

Therefore,

$$\frac{dT}{dR_o} = \frac{1}{R_o \alpha}$$

or,

$$\frac{dT}{dR_t} = \frac{1}{R_t \alpha_t}$$

Then,

$$\frac{de_o}{dT} \cdot \frac{dT}{dR_t} = - \frac{RV}{(R + R_t)^2}$$

And,

$$\frac{de_o}{dT} \cdot \frac{1}{\alpha_t} = - \frac{RVR_t}{(R + R_t)^2}$$

Where:

V	Polarizing Voltage
R	Load Resistance
R_t	Semiconductor Resistance at Temperature T
α_t	Temperature-Resistance Coefficient at Temperature T_o
R_o	Semiconductor Resistance at Reference Temperature
e_o	Output Voltage
β	Semiconductor Material Constant (Degrees Kelvin)
T	Temperature (Degrees Kelvin)

This equation was then solved for R_t with α_t given as

$$\alpha_t \cong - \frac{\beta}{T^2}$$

TABLE 2. LOCATIONS AND CHARACTERISTICS OF TIROS II TELEMETRY SENSORS

Sensor Number	Location	Temperature Range (Degrees Centigrade)	Scale Factor (Degrees per volt)	Conductance-Temperature Response
1	17 inches from base-plate center, on 130-degree radial line	-30 to +100	52	linear (± 1%) between -10 and +50 degrees Centigrade
2	17 inches from base-plate center, on 130-degree radial line	-20 to +10	12	linear (± 3%) between -20 and +5 degrees Centigrade
3	17 inches from base-plate center, on 130-degree radial line	+10 to +40	12	linear (± 3%) over entire range
4	Inside satellite top plate on 300-degree radial line	-30 to +100	52	linear (± 1%) between -10 and +50 degrees Centigrade
5	Outside satellite top plate on 300-degree radial line	-30 to +100	52	linear (± 1%) between -10 and +50 degrees Centigrade
6	Satellite top-plate, 15 inches from center on 150-degree radial line	-30 to +100	52	linear (± 1%) between -10 and +50 degrees Centigrade
7	Top of satellite side-panel No. 3	-30 to +100	52	linear (± 1%) between -10 and +50 degrees Centigrade
8	Outer surface of clock	+10 to +40	12	linear (± 3%) over entire range
9	Outer surface of battery mount	+10 to +40	12	linear (± 3%) over entire range

TABLE 2. LOCATIONS AND CHARACTERISTICS OF TIROS II TELEMETRY SENSORS (Continued)

Sensor Number	Location	Temperature Range (Degrees Centigrade)	Scale Factor (Degrees per volt)	Conductance-Temperature Response
10	Outer surface of TV transmitter No. 2	+10 to +40	12	linear (± 3%) over entire range
11	Outer surface of beacon transmitter	+10 to +40	12	linear (± 3%) over entire range
12	Outer surface of wide-angle TV camera	+10 to +40	12	linear (± 3%) over entire range

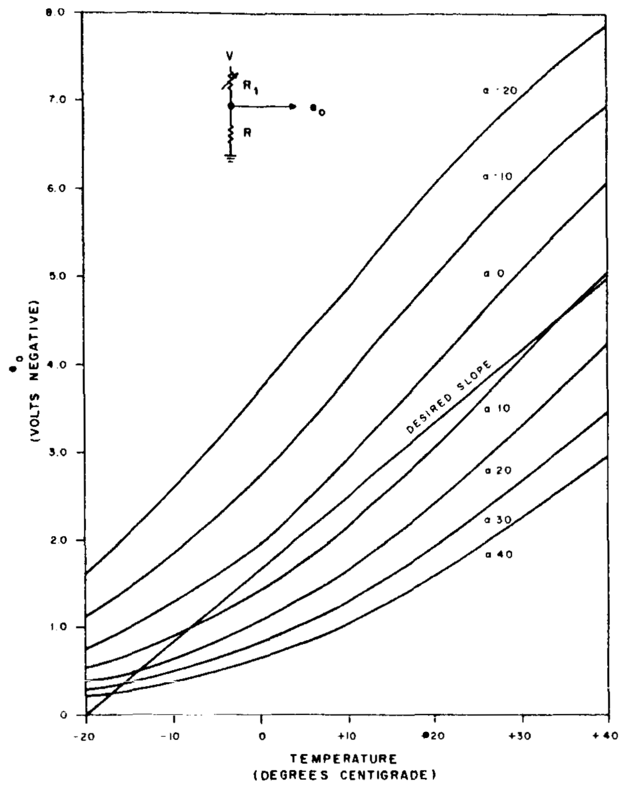


Figure 6. Expanded-Scale Sensor, Simple-Circuit Response Curves

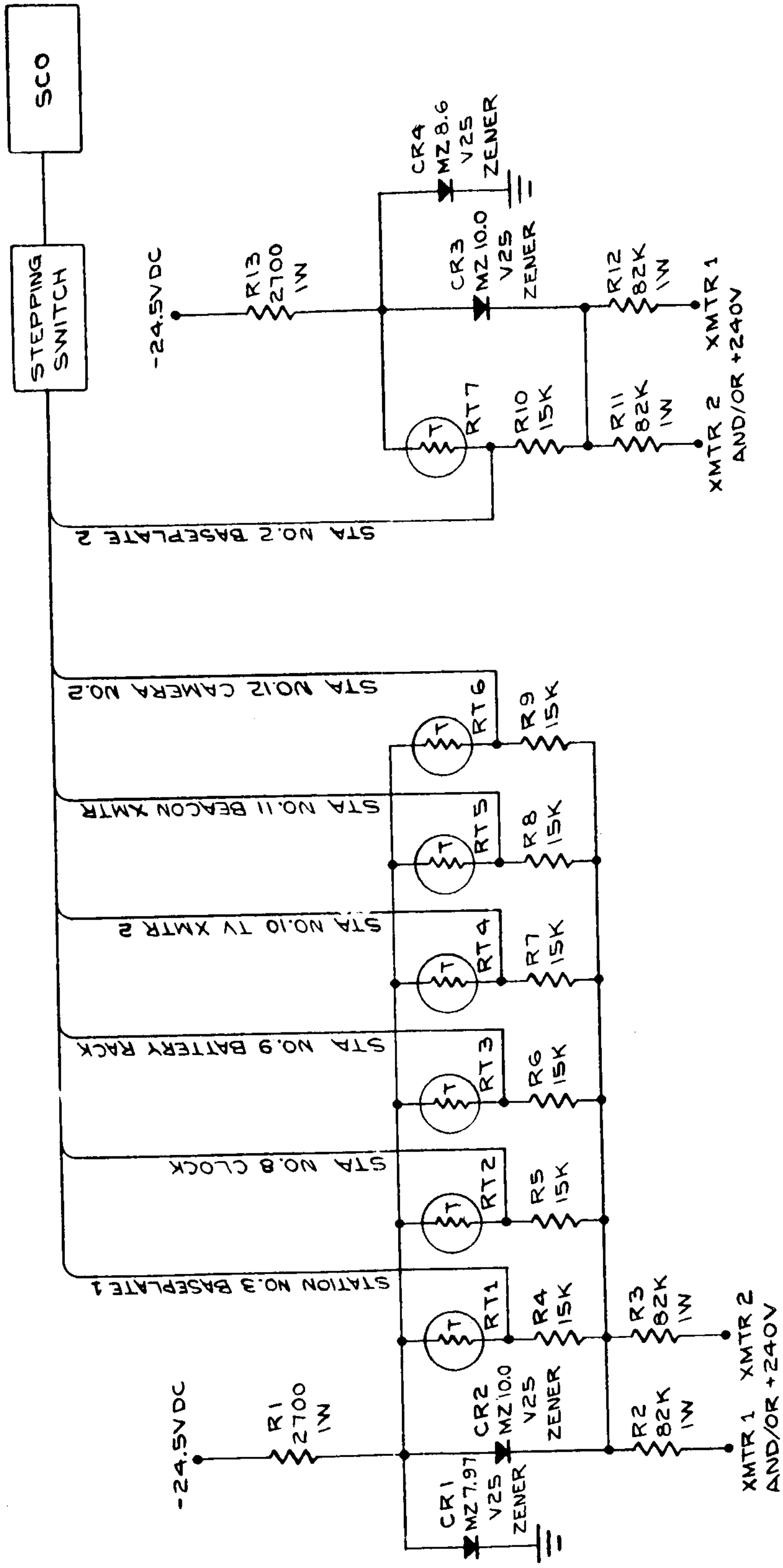
The schematic diagram of the final temperature sensor circuitry is shown in Figure 7. The theoretical response of the sensor circuits is plotted in Figures 8 and 9. The actual response of the expanded scale sensors is shown in Figure 10.

4. Telemetry Switch

The TIROS II telemetry switches, single, hermetically sealed units containing a stepping solenoid, a switch, and an associated electronic driving circuit, were the same as those employed on the TIROS I satellite. However, an external voltage divider network was added to accommodate the increase in "calibration points," and the list of parameters to be telemetered was changed.

In order to increase the number of "calibration points" from 2 to 6, the existing 2.5-volt reference supply was connected across a voltage divider which was tapped to provide output levels of -0.5, -1.0, -1.5, and -2.0 volts d-c. The power capabilities and the regulation of the existing reference supply were adequate, and no rework was required. The schematic diagram of the calibration-voltage circuit is shown in Figure 11.

Because of the increase in calibration points and the addition of four temperature-sensing points, it was necessary to alter the list of parameters to be telemetered. After a close study of the telemetry list, it was decided to delete the following:



NOTES: 1. RESISTANCE VALUES ARE IN OHMS ½W EXCEPT AS INDICATED.
2. COMPONENTS MTD ON TB-2 EXCEPT THERMISTORS (RT).
3. THERMISTORS MTD WITH STYCAST 2651 CATALYST NO.9 AT PHYSICAL LOCATION.

Figure 7. Temperature Sensor Circuitry, Schematic Diagram

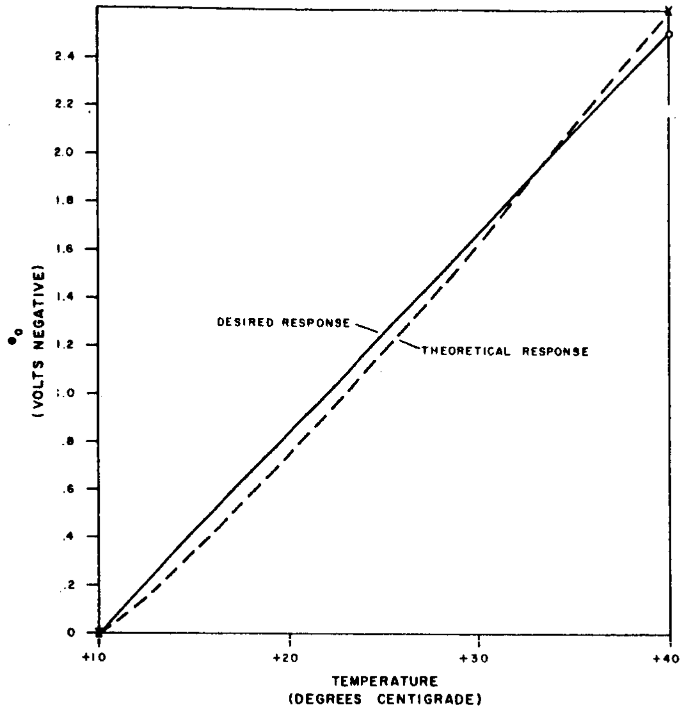


Figure 8. Theoretical Response of -20 to +10 degree Sensor

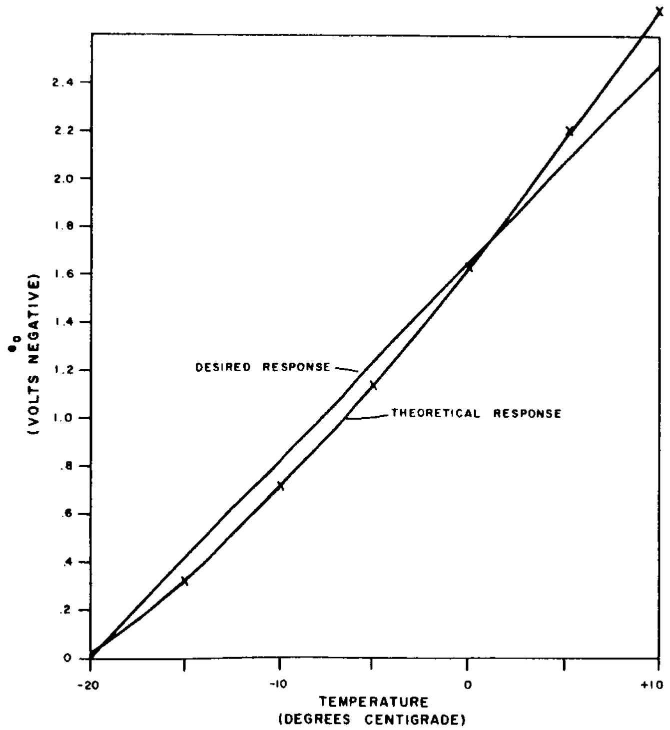


Figure 9. Theoretical Response of +10 to +40 degree Sensors

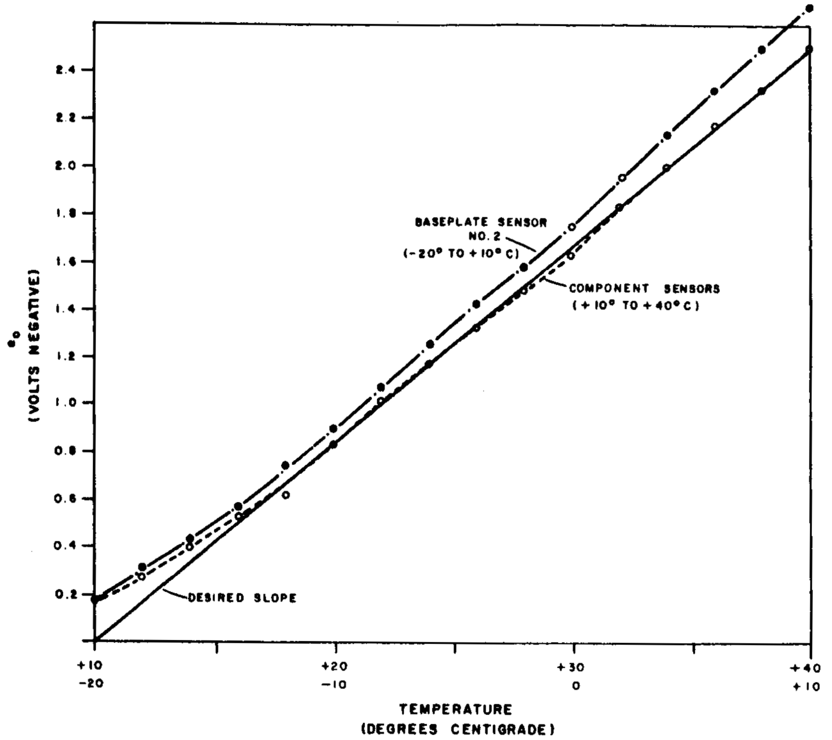


Figure 10. Observed Response of Expanded-Scale Temperature Sensors

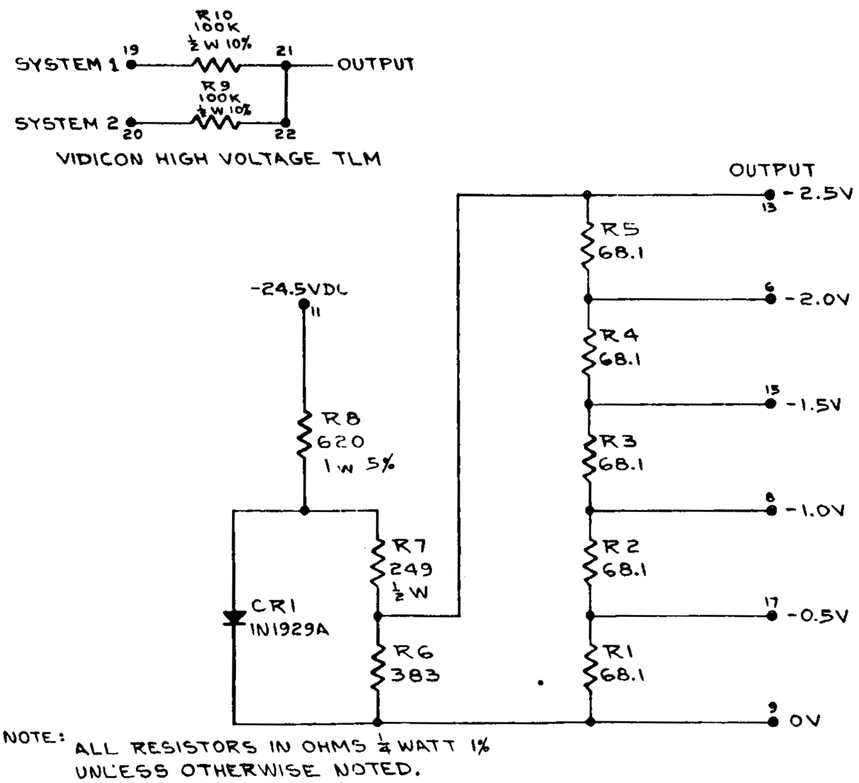


Figure 11. Telemetry Calibration-Voltage Circuit, Schematic Diagram

a. Video output of TV Camera No. 1

b. Video output of TV Camera No. 2

c. Recorder head No. 1

d. Recorder head No. 2

e. Playback amplifier No. 1

f. Playback amplifier No. 2

In addition to the above deletions, the following parameters were combined.

a. Vidicon No. 1 high voltage and vidicon No. 2 high voltage

b. TV transmitter converter No. 1 and TV transmitter converter No. 2

c. TV transmitter No. 1 driver voltage and TV transmitter No. 2 driver voltage.

The combination of these parameters liberated three additional telemetry channels for other use. Finally, a tenth telemetry channel was liberated when it was decided to integrate the sidemounted solar-cell test patch into the power supply system and thus to abandon its use for telemetry purposes.

C. REFERENCE INDICATOR SUBSYSTEMS

1. Introduction

The reference indicator subsystems is the general name given to the North Indicator Subsystem and the Attitude Indicator Subsystem. These two subsystems are considered collectively since they both supply data required for identifying cloud-picture orientation. The north indicator, consisting of nine solar-cell sensors and associated electronics, provided data from which the north direction of each TV, cloud-cover, picture could be determined. The attitude indicator, consisting of an IR sensor and associated electronics, provided data from which the attitude of the satellite's spin axis could be determined.

2. North Indicator

a. Introduction

The TIROS II north indicator subsystem was very similar to the TIROS I north indicator. The primary difference was a design modification that allowed the TIROS II north indicator to operate satisfactorily at low sun angles (α angles). This modification was necessitated by the addition of the IR experiment to the TIROS II satellite. The operating parameters of this experiment along with the parameters of the TV and power supply subsystems, dictated that the satellites attitude be maintained such that the sun angle would fall either between 70 degrees and 55 degrees, or between 35 degrees and 20 degrees.

The TIROS I north indicator was designed to operate at sun angles between 90 degrees and 30 degrees. Because of the optical-mechanical configuration of this unit, the lightbeam would "fall off" the sensor cells whenever the sun angle was less than 30 degrees. For TIROS II, the optical-mechanical configuration was modified by making the aperture slits longer, and by mounting the sensor cells closer to their associated aperture slits. Although this modification increased the "field-of-view" of the sensor cells to the desired range, the skewing effect between the light beam and the new configuration caused the amplitude of the sensor cell output to decrease, and its rise time to increase as the sun angle decreased. To compensate for this, a companion change was made in the sun-sensor electronics which increased the overall gain of that circuit. These modifications are described in more detail in their related subparagraphs.

The initial objective for the modification was to ensure reliable operation for sun angles down to 15 degrees or less. The final design of the unit provided reliable operation for sun angles down to approximately 13 degrees.

b. Functional Description

The north direction on a TV picture received from the TIROS satellite is determined by obtaining: (1) the angular position of the sun with respect to a zero reference-radius on the satellite baseplate, (2) the position of the sun with respect to the earth, and (3) the position and attitude of the satellite in its orbit with respect to the earth at the time the picture was taken.

The nine sun-angle sensor units form the first link in the data chain that provides the north-direction information. Each sensor unit consists of a sensor cell which is contained in a special mount, parallel to the spin axis, behind a slit aperture. The mounts are radially mounted 40 degrees apart around the vertical walls of the satellite housing, as shown in Figure 12.

As the satellite spins, the slits sweep across the sun, causing the sensor cells to generate "sun triggered" pulses. These pulses trigger coded multivibrators located in the sun-sensor electronics package. Because of the sensor spacing and the 9 to 12 rpm spin rate, two of these coded pulses occur during each two-second picture read-out. The coding is sequenced in such a way that any two pulses uniquely define a sun-sensor location. These pulses are amplified and shaped in the sun-sensor electronics package and applied (in coded form) to the tape-recorder electronics.

In the tape-recorder electronic circuits, the pulses are transformed into a-c signals. These a-c signals, portions of a 10-kc sine wave, have durations equal to that of the input pulses and are called "tone bursts." If the pictures are being taken in the remote mode (i.e., while the satellite is not in contact with a ground station), the tone bursts are recorded on the tape recorder, along with the corresponding video information, where they are stored until the satellite is commanded to "playback." The tone bursts (along with the video information) are then "read back" into the electronics. When the satellite is operating in a direct sequence, the "tone bursts" bypass the tape recorder and are fed directly into the electronics.

The tone bursts are used to modulate the TV transmitter which sends the information to earth. Here the video and sun-angle information is received by the TV receiver. The

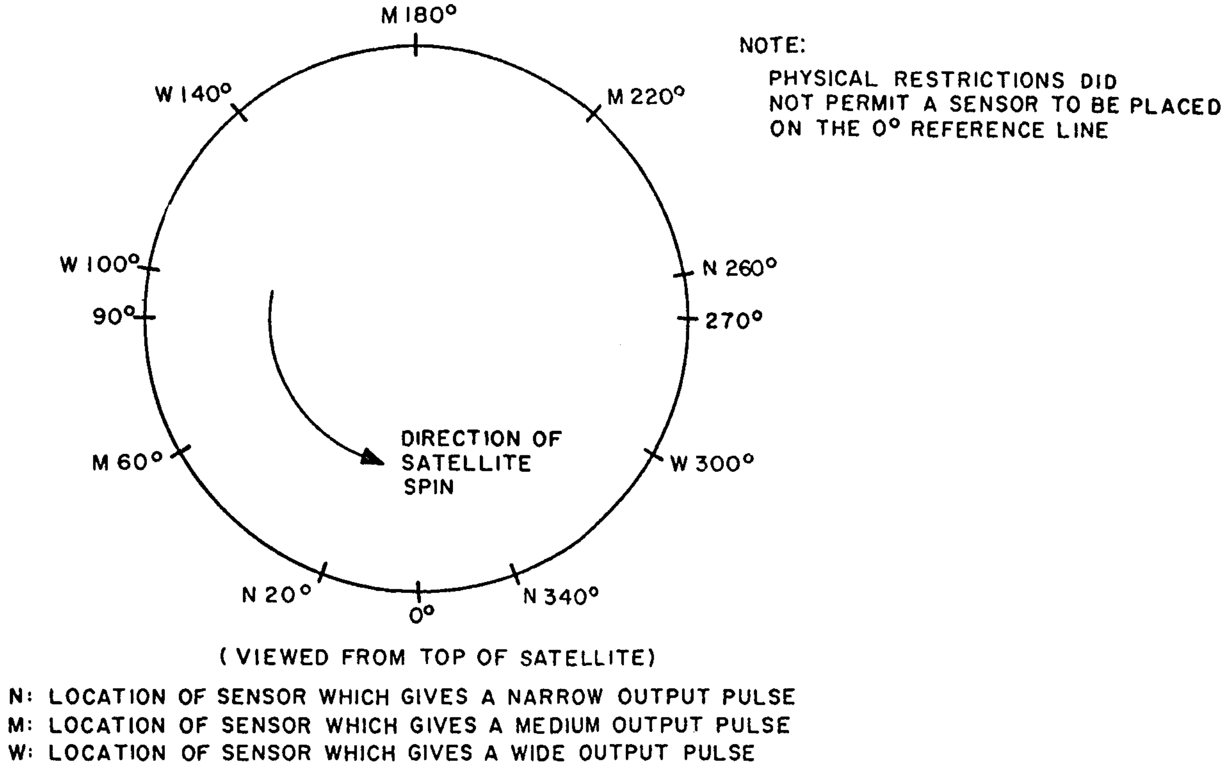


Figure 12. Locations of Sun-Sensor Units on Satellite Baseplate

sun-angle bandpass filter separates the sun-angle information from the video signal, after which the tone bursts are applied to the sun-angle computer. The computer identifies the particular baseplate-referenced sun sensor associated with the tone bursts corresponding to a given bit of video information by using the sensor coding scheme (described in the section on sun-sensor electronics). It then relates the occurrence times of these bursts with the initiation of the video subcarrier, which corresponds to the time at which the picture was taken, and computes the sun angle. Simultaneously, the video information and the sun angle from the computer are displayed visually and photographed. Using the sun angle on a photograph along with orbital data corresponding to the time the TV picture was taken, the north direction can be determined and placed on the photograph.

c. Sun-Sensor Electronics

(1) General

The sun-sensor electronics consisted of nine sensor cells, equally spaced around the periphery of the satellite, and associated pulse-shaping circuits. A block diagram of the sun-sensor electronics is shown in Figure 13.

The sensor cells were divided into three groups of three cells each. The outputs of one group were fed into a pulse-shaping circuit which produced a long duration

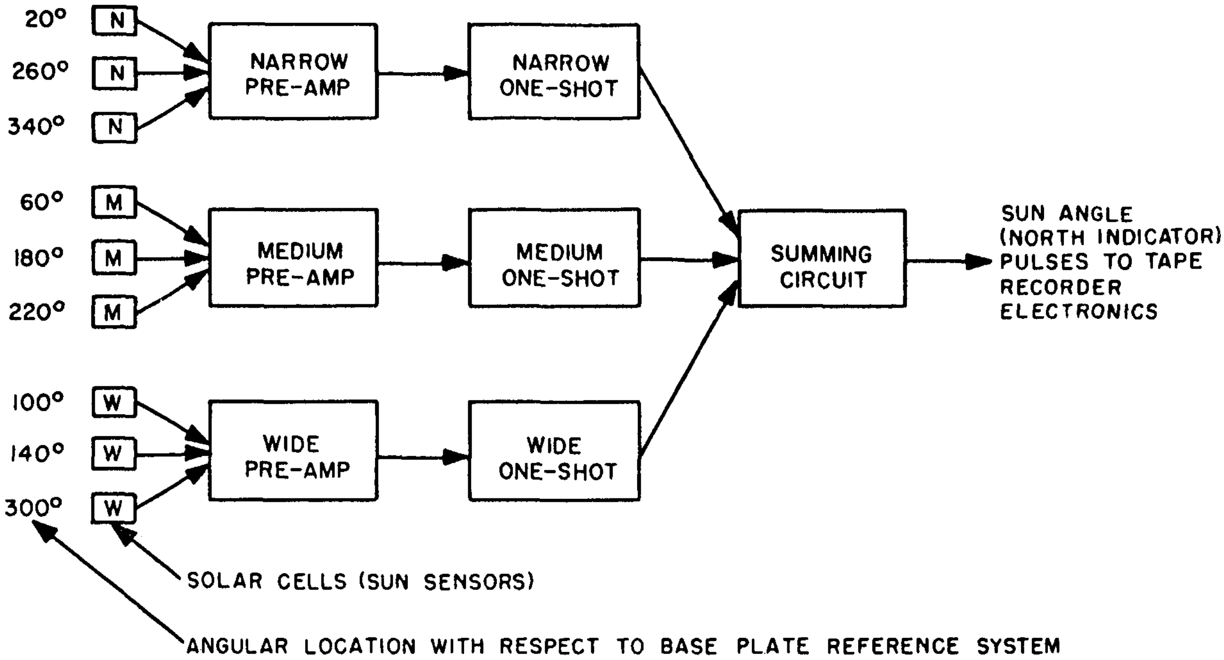


Figure 13. Sun-Sensor Electronics, Block Diagram

(50 to 85 millisecond) pulse; the outputs of the second and third groups were fed to circuits producing medium-duration (120 to 175 millisecond) and short-duration (205 to 290 millisecond) pulses, respectively. Because of the satellite's spin rate and the camera's vertical sync rate, two "sun-pulses" were produced for each TV picture. The "sun-pulses" and their associated TV picture were either transmitted directly to ground or stored on the TV tape recorder for transmission during a playback. The transmission of the "sun-pulses" and TV pictures occurred simultaneously.

By judicious interleaving of the sensor cells from each group, a pulse coding system was evolved which allowed the orientation of the satellite to be determined merely by examination of the sequence (long-long, long-short, etc.) of the two pulses. (This "examination" was performed at the ground station by the sun-angle computer.)

The basic requirements, and the initial development and design of the sun-sensor electronics are described in Volume I of the TIROS I Final Report (Reference 1). Except for the modification described in the following subparagraph, the functional description contained in the TIROS I Final Report is also applicable to the TIROS II sun-sensor electronics.

(2) Description of Modifications

The schematic design of the TIROS II sun-sensor electronics is shown in Figure 14§. The schematic is the same as that for TIROS I except the resistive and capacitive elements were removed from the emitter circuit of Q3, and a 10-microfarad capacitor was added in parallel with capacitor C3.

Because of the slow rise time of the TIROS II pulses, the resistive and capacitive elements caused excessive degeneration of the sun-pulse signals. Removal of these elements eliminated the degenerative action and thus increased the gain of the stage.

Adding the 10-microfarad capacitor in parallel with capacitor C3 increased the coupling between the preamplifier and the one-shot multivibrator. This addition permitted the one-shot to be triggered by the slowly rising pulses that existed in TIROS II.

(3) Testing

The modified sun-sensor electronics circuits for each of the TIROS II satellites were subjected to the following tests:

(a) Temperature

(b) Thermal Vacuum

(c) Vibration

(d) Temperature

(e) Go, No-Go Check

Figure 15 shows the test circuit used in developing and testing the sun-sensor electronics. This test circuit is used to simulate the output of an actual sensor cell at low sun angles. The output characteristics were based on laboratory measurements of sensor-cell outputs as well as analytical studies of sensor-cell output parameters.

For the first temperature test, the sun-sensor electronics was placed in a Tenny vacuum chamber and fed from the test circuit (sun-pulse simulator). After it was determined that the sun-sensor electronics was operating correctly, recordings were made of both the minimum pulse amplitude required to trigger the monostable multivibrators (one shots), and the width of the output pulse from each multivibrator. These recordings were made at temperatures of -10, +25, and +60 degrees centigrade.

The thermal-vacuum test was similar to the temperature test. The electronics were placed in a bell-jar vacuum chamber and were fed from the sun-pulse simulator. The pressure within the chamber was reduced to 5×10^{-6} mm of Hg and the widths of the sun-sensor output pulses recorded. These recordings were made for temperatures of -10, +25, and +55 degrees centigrade.

After successful completion of the temperature test and thermal-vacuum test, the sun-sensor electronics boards and their associated sensor cells were mounted on the

§ This illustration is printed on a foldout page located at the rear of this Section.

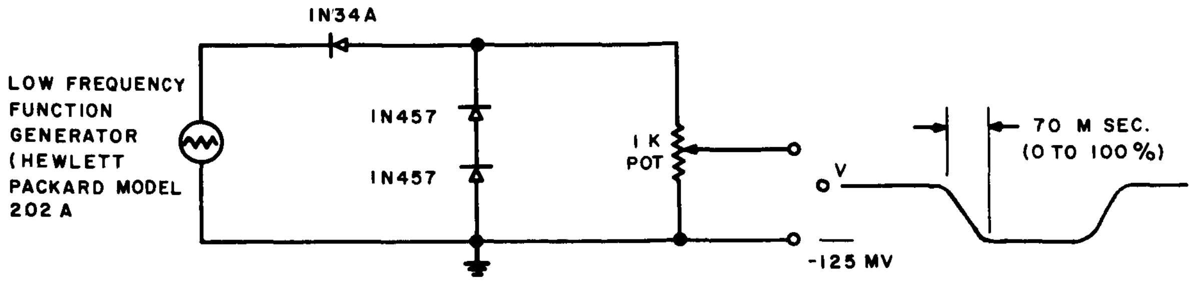


Figure 15. Sensor-Cell Output Simulator

bracket plates. The assembled units were then subjected to a vibration test. After passing the vibration test, the assembled units were subjected to a final temperature test.

This final temperature test was performed using the actual sensor-cell outputs to trigger the one-shot multivibrators. The sensor cells were energized by manually chopping the light from the light source. Since the satellite's "hat" was not in place, the light rays fell directly on the cells without first passing through an aperture slit. Because of this, the test did not simulate the correct input pulse characteristics. However, it did provide a check on the sensor cells and the circuit interconnection wiring. (It should be noted that circuit operation had been checked using the correct inputs in the previous tests.)

The Go, No-Go check was the final test in the test series. Prior to commencing this test, the sensor cells and sun-sensor electronics were mounted behind the aperture slits in the satellite's hat, the interconnecting harness was wired in, and the cells were aligned with respect to the aperture slits*. The Go, No-Go test consisted of triggering the circuits by energizing the sensor cells with a spot light, which was directed at the aperture slits, and manually chopping the light rays. The output pulse widths of the various sun-sensor units were recorded.

(4) Universal Sun Angle Correction Curve

The Universal Sun Angle Correction Curve, shown in Figure 16, was used to compensate for errors in the computed satellite-orientation due to variations in the sun angle (α angle). The curve was plotted from data that was obtained during a "Sun Calibration Run" which was performed on satellite model F2. The calibration run consisted of rotating the satellite at 10 rpm in direct sunlight, and recording the angular displacement of sun-sensor electronics' output pulses with respect to an angular reference on the satellite's base plate. These recordings were made at various α angles. The results obtained for each α angle were compared, and variations between sets of recordings were measured and converted into correction factors to be applied to the computed satellite-orientation. An explanation of the curve's shape follows.

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*The mechanical alignment procedure is described in the paragraph entitled "Sun-Sensor Mechanical Configuration."

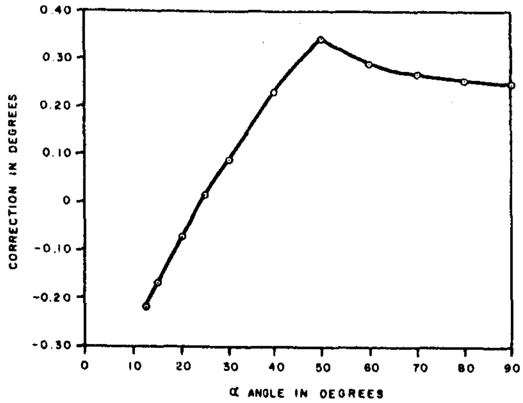


Figure 16. Universal Sun-Angle Correction Curve

The satellite's orientation with respect to the sun is computed by the sun-angle computer (ground station) for each TV picture. The sun-angle computer bases its computations on the fact that a particular sun sensor is activated only when the sun is precisely aligned with the associated sensor cell. Actually, because of two independent effects, this basis for computations is not always valid. The first effect, a keystoning effect, results from the geometric relationship of the aperture slit and the sensor-cell. This keystoning effect causes an increase in the width of the light beam in the plane of sensor-cell's active surface, and thus tends to cause the associated one-shot multivibrator to be triggered before the sun is fully in line with the sensor cell. The second effect is a degradation of the sensor-cell output pulse (increase in rise time and decrease in amplitude) that occurs as the α angle decreases. This second effect tends to cause a delay in the triggering of the one-shot multivibrators. For α angles of less than 50 degrees, the second effect is greater than the first; conversely, for α angles in excess of 50 degrees, the first effect is greater than the second.

Referring to Figure 16, note that when the α angle is 90 degrees, a correction factor of +0.25 degrees should be subtracted from the computed orientation angle. This correction factor, which is taken into consideration throughout the entire curve, compensates for the fact that the sun subtends 0.5 degrees. As the sun angle decreases toward 50 degrees, the required correction factor increases and results in a further reduction in the computed orientation angle. This increase in correction factor is required to compensate for the keystoning effect.

As the sun angle drops below 50 degrees, the second effect (degradation of the sun-sensor output pulse) becomes the predominant effect. Thus the correction factor becomes less and less positive. When the sun angle reaches 24 degrees, the effect of signal degradation becomes pronounced enough to delay the triggering of the multivibrators until after the sun has passed the point of true alignment with the sensor cell. Accordingly, a negative correction factor is prescribed. Subtraction of this negative signal results in an increase in the computed orientation angle and thus compensates for the late triggering of the multivibrators.

d. Sun-Sensor Mechanical Configuration

(1) Development and Design

The mechanical configuration of the TIROS II sun-sensor units was similar to that of the TIROS I units. The differences between the two units were those changes that were required for accommodating sun angles of less than 30 degrees. The basic design considerations for the sun-sensor units are described in Volume I of the TIROS I Final Report (Reference 1). The modifications that were required for accommodating sun angles of less than 30 degrees are described here.

The original sun-sensor units were designed to operate at sun angles between 30 degrees and 90 degrees, and, therefore, required modification before they could be used on the TIROS II satellite. Although it would have been desirable to establish a design which would allow the units to operate at 0-degree sun angles, there were several factors which made it impracticable to attempt such a design. These factors were:

(a) The sensor cell had to be mounted parallel to the aperture slit and the satellite's spin axis in order to avoid the introduction of complex geometric considerations.

(b) The amplitude of the sensor-cell outputs was proportional to the normal component of the sun's rays impinging on its surface, and thus approached zero as the sun angle approached 0 degrees.

(c) The width of the light beam striking the sensor cell was proportional to the length of the light path between the aperture slit and sensor cell. Because of this relationship, the width of the light beam became excessive at low sun angles and caused a shift in the sensor-cells triggering point.

After consideration of these three factors, RCA concluded that it would be impractical, from a mechanical standpoint, to attempt to accommodate sun angles of less than 10 degrees. (Later, because of electrical consideration, this lower limit was set at 13 degrees.)

Figure 17 shows the relative positioning of the sensor cell and the aperture slit within a sun-sensor unit. As can be seen from the illustration, the X and Y dimensions determine the range of sun angles (α angles) within which the sun's rays can strike the sensor cell. Smaller sun angles could have been accommodated by increasing the height of the aperture slit (X dimension), or by decreasing the perpendicular distance from the solar cell to the plane of the aperture slit (Y dimension), or by adjusting both dimensions.

Initial studies showed that, because of the physical restrictions imposed by the satellite's "hat" structure, the X dimension could not be increased sufficiently to even approach the desired α angle. Therefore, this approach was abandoned and it was decided to attain the design objective (10 degree lower limit) by adjustment of the Y dimension.

Since the sensor housings developed for TIROS I could not accommodate any appreciable increase in the Y dimension, they could not be used on the TIROS II satellite. Accordingly, a decision was made to abandon the single integrated unit of TIROS I, shown in Figure 18a in favor of the alternate arrangement shown in Figure 18b. In the alternate

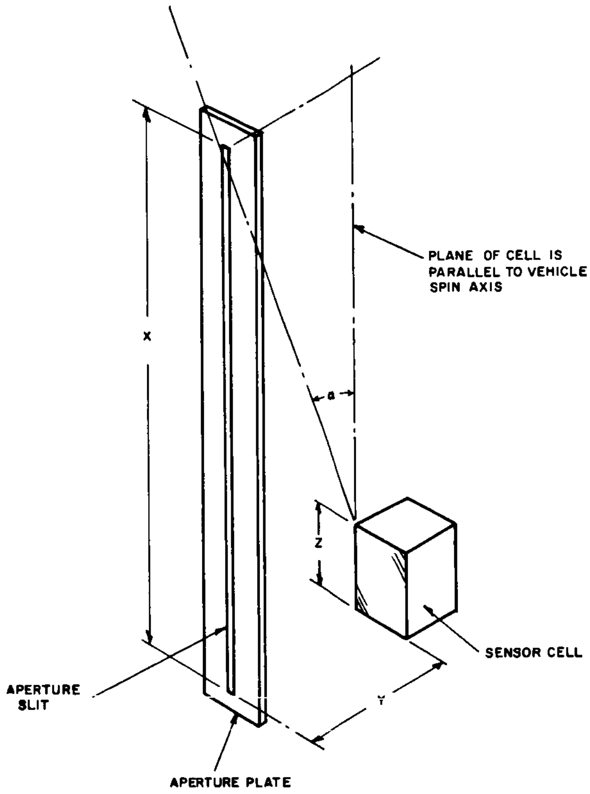


Figure 17. Sun-Sensor Unit, Basic Configuration

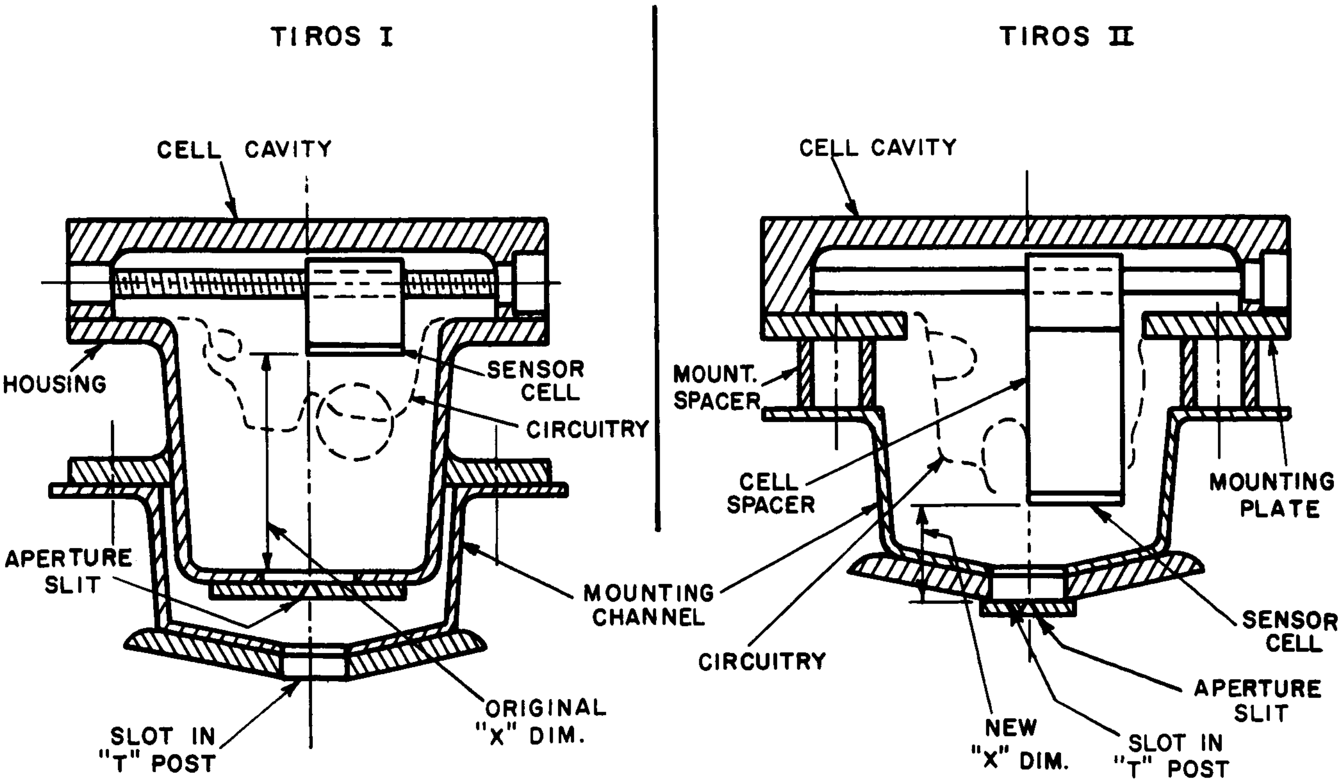


Figure 18. Comparison of TIROS I and TIROS II Sun-Sensor Units

arrangement, the cell cavity was affixed to a flat plate mounted inside the satellite's hat assembly, and the aperture plate was mounted between adjacent solar-cell panels, on the outboard surface of the "T" posts.

Implementation of the alternate arrangement required a modification to the cell cavities, and the design and fabrication of several new parts; namely, mounting plates, cell spacers, different aperture plates, and mounting spacers. The use of the cell spacers and mounting spacers was dictated by the space requirement for the circuit components. (In this new configuration the circuit components had to be installed in the area between the mounting plate and the mounting channel.)

Figure 19 depicts, in exploded-view form, the arrangement of the parts within the TIROS II sun-sensor unit. The circuit board, and the cell-cavity and sensor-cell combination are rigidly affixed to the mounting plate. The mounting holes of the plate were designed to allow lateral positioning of the plate, and thus to provide for adjustment of the position of the cell cavity. It should be noted that the layout of the mounting plate was such that it could be used as a direct replacement for the TIROS I "housing" without requiring any physical changes to the circuit-board mounts or to the harnessing between the various sensors.

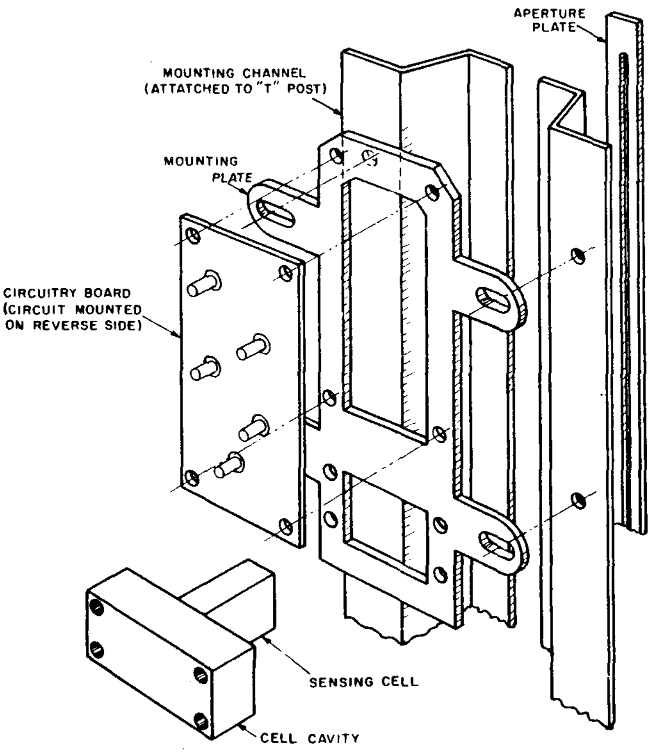


Figure 19. TIROS II Sun-Sensor Unit, Exploded View

(2) Alignment Procedure

Since the aperture plate and the sensor cell were no longer housed as an integrated unit, a new method had to be devised for aligning the sensitive axis of each sensor unit with its respective radial line-of-site. The following is a summary of this new procedure:

(a) The first step in the alignment procedure was to mount the aperture plates on their respective "T" posts with their centerlines parallel to the satellite's spin axis and normal to their associated radial lines. This step of the alignment was accomplished with the satellite mounted on an indexing head. With the satellite mounted in this fixture, an alignment scope was set up so that its line-of-sight passed through the satellite's spin axis. The satellite was then rotated until its 0-degree scribe mark was in register with the cross hairs in the scope's line-of-sight. Using the scope's cross hairs for reference, the 0-degree aperture slit was aligned with the 0-degree radial line and locked into place. The satellite was then rotated in increments of 40 degrees and each of the nine aperture slits was aligned with its associated radial line and locked into place.

(b) The second step of the physical alignment procedure was the alignment of the leading edge of each sensor cell with the plane defined by the satellite's spin axis and the edge of the aperture slit. This portion of the alignment procedure was accomplished using essentially the same set up as had been employed in the first step of the procedure. The satellite was rotated on the indexing head until the leading edge of one of the apertures coincided with the vertical reticle of the alignment scope. The cell carrier lead screw was then adjusted until the leading edge of the sensor cell was aligned along the same radial line as the aperture slit. This procedure was repeated for each of nine sensor units.

3. Attitude Indicator

a. General

The operation of the horizon-scanner attitude indicator was not completely successful in the TIROS I satellite. Spin-rate data was the only useful operational data; several deficiencies prevented utilization of the data for operational attitude determination. Basically, these deficiencies were as follows:

(1) The spectral response of the bolometer was relatively flat between 1.8 and 30 microns. This wide spectral response caused the bolometer to produce outputs in response to cloud transitions as well as in response to sky-earth and earth-sky transitions. These spurious transition pulses made data reduction extremely difficult.

(2) R-C time constants within the attitude indicator electronics were such that they caused double differentiation of horizon transitions. The double differentiation of the transition pulses caused overshoots and hence introduced spurious signals which added to the difficulty of the data reduction task.

(3) The long recovery time of the attitude-indicator electronics caused a loss of the horizon pulse whenever a spurious pulse occurred less than 250 milliseconds before a valid transition pulse.

(4) The low-frequency cut-off of the horizon-scanner amplifier was approximately 10 cps. Because of this, maximum amplitude pulses could be produced only when the horizon sensor scanned normal to the horizon; when the scan was oblique to the earth's surface, the pulses were severely attenuated. Useful outputs could be obtained only when the "earth-roll angle" was greater than 100 degrees.

(5) The threshold required for producing a 3-kc tone burst (indicating an earth-sky or sky-earth transition) was set at an equivalent earth temperature of 220 degrees Kelvin when actually the earth temperature, as observed from TIROS I data, was approximately 275 degrees Kelvin. This caused the system to be oversensitive and thus resulted in the magnification of the deficiencies in other portions of the circuitry.

Because of the deficiencies that were detected in the TIROS I attitude indicator, several significant changes were made before the circuitry was integrated with the remainder of the TIROS II satellite. Basically, these changes were as follows:

(1) A redesign of the amplifier circuit to improve its operating characteristics.

(2) A change in the form of signal processing so that the analog output of the horizon-scanner amplifier was directly transmitted, instead of first being digitized.

The latter of the two changes resulted in a simplification of the satellite-borne equipment. Also, this change allowed the actual analog horizon data to be recorded at the CDA stations for subsequent evaluation of the earth's heat radiation, spurious "cloud" pulses, and the motion of the satellite's spin-axis.

b. Description of Design Changes

In order to correct the deficiencies in system performance, it was decided to completely redesign the horizon-scanner amplifier, while retaining the original bolometer and its associated optics and mechanical assembly. The new amplifier had to meet relatively stringent requirements to be compatible with system requirements. Basically, the design requirements were as follows:

(1) Low Noise Figure. Because of the low amplitude signal from the bolometer (between 10 and 100 microvolts) the amplifier noise had to be held to an absolute minimum.

(2) Low Frequency Cutoff. In order to accommodate signals resulting from scanning the horizon at oblique angles, the low frequency cutoff had to be below 0.5 cps.

(3) Low Power Consumption. Since power had to be constantly applied to the horizon-scanner amplifier, the power consumption of the amplifier had to be held to a minimum.

The schematic diagram of the TIROS II horizon-scanner amplifier is shown in Figure 20. The unit consisted of a five-stage amplifier which was essentially d-c coupled except for the input and output circuitry. D-c coupling was used to eliminate the need for high value coupling capacitors.

In order to eliminate the possibility of double differentiation of low-frequency signals from the bolometer, only one R-C network was used to perform differentiation. This differentiation was accomplished by the time constant represented by capacitor C3, the source impedance of transistor Q1, and the input impedance of transistor Q2. The only other time constants, represented by capacitors C4 and C5 and the input impedance of the beacon subcarrier oscillators, were relatively long as compared to the time constant associated with capacitor C4.

Emitter follower Q1 was included to provide a high-impedance load on the bolometer. This was necessary because the bolometer was effectively a resistance that varied with temperature; and any loading effect by the input circuitry would have caused the bolometer output voltage to also vary with temperature. Transistors Q1 and Q2 were biased for an emitter current that would provide an optimum noise figure.

Resistor R6 was employed to provide negative feedback from transistor Q4 to transistor Q2, and thus to establish the operating points of transistors Q2 through Q5. It should be noted that this feedback loop provided more attenuation to d-c than to a-c, and therefore ensured good d-c stability. The resultant gain for a-c signals was approximately 75 db while the d-c gain was approximately 40 db.

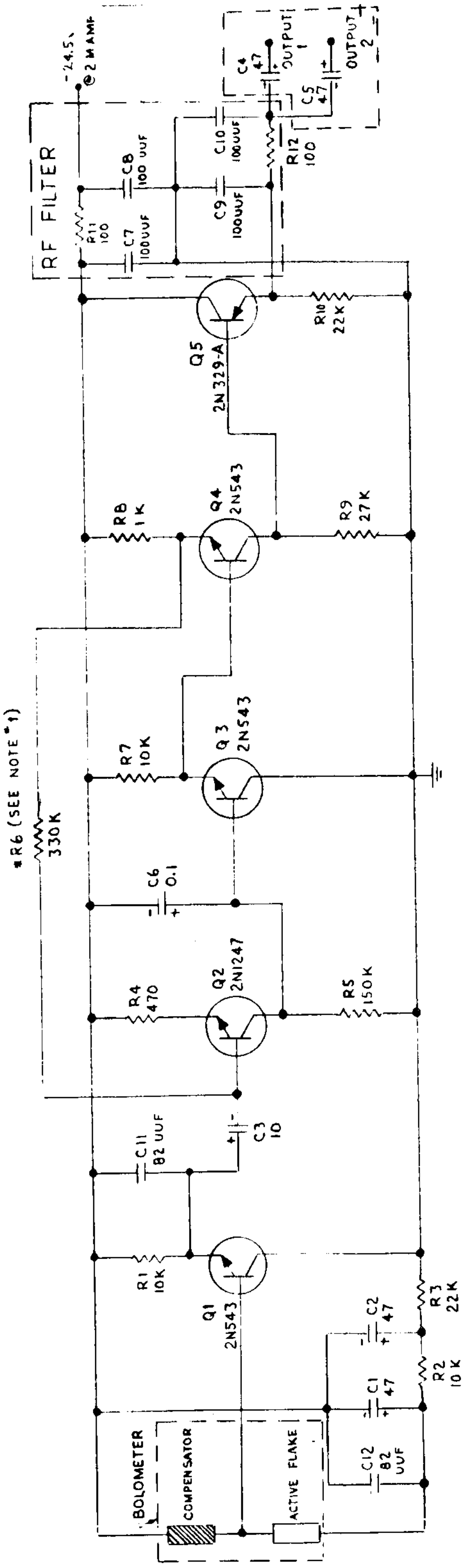
The RF filter was identical to that employed on the TIROS I horizon-scanner amplifier. This filter was required because of RF interference from the beacon and TV transmitters.

Operating points of the various stages were carefully selected to provide the minimum collector current consistent with stable operation. The total power consumption of the horizon-scanner amplifier was less than 50 milliwatts.

D. ELECTRICAL POWER SUPPLY SUBSYSTEM

1. General

Electrical power for all of the satellite's requirements was generated by a solar-energy converter, which consisted basically of an array of 9120 silicon solar cells, mounted on the top and sides of the satellite structure. Since the angle of illumination of the cells varied, and since the satellite was in the shadow of the earth during part of its orbit, a secondary power supply, consisting of 63 nickel-cadmium storage batteries, was included in the subsystem to maintain power continuity. The storage batteries had a total capacity of approximately 275 watt-hours. The solar-cell array and storage batteries were connected in such a manner that the batteries were charged when the solar cells were active, and that excess solar-cell output was used to power the electrical load directly. Precautions were taken to prevent internal circulating currents through the power-source interconnections, and to preclude the total loss of power in the event that a short circuit occurred in one of the cells or batteries.



NOTES:
1- * NOMINAL VALUE ADJUST FOR 12V AT Q5 EMITTER.
2- ALL CAPACITORS IN UF - 35 V, ALL RESISTORS 1/4 W
UNLESS OTHERWISE SPECIFIED.

Figure 20. Attitude Indicator, Schematic Diagram

The storage batteries were electrically connected in three independent groups, each of which was connected to the solar-cell supply through its own current regulator to prevent an excessive rate of charge. The excess power was diverted through a bypass regulator to the main battery-output bus. During the orbital night, when the solar cells were passive, silicon diodes in each series row of solar cells prevented the storage batteries from discharging into the solar cells. A similar function was performed by diodes which were included in each series row of solar cells located on the lateral surface of the satellite. Because of the satellite's rotation, each series row of solar cells on a lateral surface was alternately illuminated and then darkened. The diodes prevented the darkened solar-cell rows from loading the illuminated rows.

The storage batteries provided a relatively constant voltage across the solar cells; thereby, isolating them from variations in the electrical load. The storage batteries were charged by the solar cells during the orbital day and supplied all equipment loads during orbital night. In addition, during the orbital day, the batteries supplied the difference between peak power requirements and the solar-cell output.

The basic development and design, and the functional operation of the electrical power supply subsystem is described in Volume 1 of the TIROS I Final Report (Reference 1). The following text is limited to discussions of changes made to the solar-cell array and to tests that were conducted on the storage batteries.

2. Solar-Cell Array

The basic solar-cell array was similar that employed on TIROS I. The primary differences were: (1) a patch of 80 solar-cells, which had been used as a source of telemetry data for TIROS I, was rewired and became part of the power supply portion of the array*; and (2) a group of 5, series-connected, solar-cells was specially mounted so that its temperature could be monitored and telemetered to the interrogating CDA station. These modifications resulted in an slight increase in the total instantaneous power output of solar-cell array.

The use of the side-mounted solar-cell patch for telemetry purposes was abandoned for two basic reasons. First, the data supplied by the side-mounted patch was redundantly supplied by a solar-cell patch that was mounted on the satellite's top surface. Second, the data supplied by the top-mounted patch was more readily evaluated than the data received from the side-mounted solar-cell patch. The difficulty experienced in evaluating the output of the side-mounted patch was due to the fact that the satellite's rotation caused the patch to be alternately exposed to sunlight and darkness. Since the output of a solar-cell patch is directly proportional to the normal component of the light rays impinging on its surface, the output of the solar-cell patch was zero during one-half of a satellite rotation and varied at a nearly sinusoidal rate during the other half of the rotation. In order to evaluate the output of the side-mounted solar-cell patch, it was necessary to compute the incidence angle between the solar radiation vector and the plane of the solar-cell active surface for the time at which telemetry readout occurred. Because of the reliability of

*A second patch of solar cells, mounted on the top of the satellite, are still used for telemetry purposes.

the data supplied by the top-mounted solar-cell patch, it was decided to convert the side-mounted patch for power supply use, and thus to increase the peak power output of the overall solar-cell array.

The group of 5 series-connected solar cells was resistance loaded and bonded to the top surface of the satellite. A small hole was drilled through the satellite structure and the solar-cell mounting substrate so that a telemetry thermistor could be affixed to the underside of the group of solar cells. This was an improvement over the TIROS I solar-cell temperature-sensing technique in which the temperature sensors were located behind the solar cells on the satellite's "skin".

The resistance load for the shingle was selected so that the solar-cells that comprised the telemetry shingle would operate at the same efficiency as the other solar cells mounted on satellite's top surface.

3. Storage Batteries

a. General

During TIROS I it was noted that the cellulose-acetate separators of the nickel-cadmium storage cells deteriorated at operating temperatures in excess of +40-degrees centigrade. Furthermore, it was indicated that this deterioration was actually an acceleration of a gradual breakdown that occurred at all temperatures. In order to preclude the possibility of launching a TIROS satellite whose battery rack was approaching the point of fatigue, the storage batteries which were residual from TIROS I were extensively tested. The results of these tests showed that the batteries had deteriorated. Therefore, new batteries were procured for the TIROS II satellite.

b. Battery Test Program

The initial phase of the battery test program was the testing of the batteries which had been procured during the TIROS I project and installed on satellites D-1, D-2, T-2, and T-1A. These tests were designed to facilitate detection of any significant performance-degradation that might have occurred between the test date and the date on which the batteries were delivered for integration into the TIROS I satellites. In order to pass the test requirements, each battery row had to have a capacity of 3.5 ampere-hours when discharged at a rate of 1.0 ampere to an end voltage of 25.2 volts.

After it was determined that the residual batteries were unable to meet the minimum test requirements, new batteries were procured and packaged for inclusion in TIROS II satellites F1, F2, and F4. Results of the tests performed on these new batteries are listed in Table 3, as are the results of the tests conducted on the batteries which were residual from TIROS I.

Table 4 is a listing of the storage batteries that failed during the test program and which were subsequently cut open in an effort to determine the cause of failure. The amount of separator deterioration varied from cell to cell, but, generally, it was a

TABLE 3. BATTERY EXAMINATION DATA

Cell Identification	Date of Purchase	Satellite	TIROS I Test Data			TIROS II Test Data			Condition of Cell When Opened
			Date of Test	End-of-Charge Voltage	Ampere-Hour Capacity	Date of Test	End-of-Charge Voltage	Ampere-Hour Capacity	
C 86	Late 1959	D-1	1/12/60	1.45	3.5	8/24/60	1.62	1.5-2.5	Sep. Deteriorated
C 96	Late 1959	D-1	1/12/60	1.43	3.5	8/24/60	1.70	3.4	Sep. Deteriorated
C 88	Late 1959	D-1	1/12/60	1.46	3.5	8/24/60	1.82	3.0	Sep. Deteriorated
C 104	Late 1959	D-1	1/12/60	1.43	3.5	8/24/60	1.48	3.4	Sep. Deteriorated
C 111	Late 1959	D-1	1/12/60	1.44	3.5	8/24/60	1.64	1.5-2.3	Sep. Deteriorated
C 270	Late 1959	D-2	1/11/60	1.54	3.8	---	---	---	Sep. Deteriorated
C 303	Late 1959	D-2	1/11/60	1.47	3.5	8/24/60	1.64	---	Sep. Deteriorated
C 246	Late 1959	D-2	1/11/60	1.44	3.8	8/24/60	1.64	---	Leaked Electrolyte (Not Cut Open)
C 260	Late 1959	D-2	1/11/60	1.52	3.8	8/24/60	1.64	---	Internal Short
C 539	Jan. 1960	Spare	2/16/60	1.46	3.6	8/28/60	1.46	3.9	Sep. Not Deteriorated
C 540	Jan. 1960	Spare	1/11/60	1.46	3.9	8/29/60	1.50	3.9	Sep. Not Deteriorated
C 177	Late 1959	T-1A	2/11/60	1.60	3.9	---	---	---	Sep. Deteriorated
C 357	Late 1959	T-1A	2/11/60	1.52	> 3.6	8/29/60	1.50	---	Sep. Deteriorated
C 161	Late 1959	T-1A	2/11/60	1.61	> 3.6	8/29/60	1.50	---	Sep. Deteriorated
C 171	Late 1959	T-1A	2/11/60	1.61	> 3.6	8/29/60	1.50	---	Sep. Deteriorated

TABLE 4. BATTERY TEST RESULTS

TIROS I Satellite Designation	TIROS II Satellite Designation	Date of Test	Ampere-Hour Capacity			Highest Voltage During Charge-Volts			Reject or Accept
			Row 1	Row 2	Row 3	Row 1	Row 2	Row 3	
D-1	F-1	7/27/60 to 7/28/60	2.5	3.0	2.8	33.8	33.7	33.6	Reject
D-1	F-1	7/29/60 to 7/30/60	3.0	3.1	3.0	24.0	33.6	33.6	Reject
D-1	F-1	8/2/60 to 8/3/60	2.5-3.0	3.1	2.5-3.0	34.4	34.8	34.1	Reject
D-1	F-1	8/24/60	2.0-2.3	2.7-3.0	2.5	34.0	35.7	35.3	Reject
T-2	T-2A	7/30/60 to 7/31/60	3.7	3.5	3.6	31.9	32.6	31.7	Accept
T-1A	F-4	7/25/60 to 7/26/60	3.5-3.6	3.5-3.6	3.5-3.6	32.5	31.8	31.7	Accept
T-1A	F-4	10/3/60 to 10/4/60	3.1	3.0	3.0	31.8*	32.3*	32.7*	Reject
T-1A	F-4	10/15/60 to 10/16/60	2.7	2.8	2.8	31.5*	31.6*	32.4*	Reject
D-2	F-2	8/4/60 to 8/5/60	2.5-3.0	0.6	3.2	34.5	32.5	34.3	Reject
---	New F-1	8/5/60 to 8/6/60	4.0	3.7	3.9	31.7	31.3	31.7	Accept
---	New F-1	8/8/60 to 8/9/60	3.9	3.9	3.8	31.6	31.4	31.8	Accept
---	New F-2	9/1/60	3.8	3.9	3.7	30.8	30.6	30.9	Accept
---	New F-4	10/6/60	$\geqq 3.9$	$\geqq 3.9$	$\geqq 3.9$	$\geqq 31.2$	$\geqq 31.2$	$\geqq 31.2$	Accept

* An insufficient number of readings were taken so that maximum voltage was not observed or recorded.

maximum at the ends of the battery. In addition to the obvious deterioration, the separators appeared to have lost a certain amount of tensile strength. This was considered to be evidence of a slight, general deterioration of the separators.

Two storage batteries (C539 and C540), which were spares and thus had not been part of a satellite power supply, were cut open for purposes of comparison. These two cells, both of which were approximately six months old, showed little or no change in electrical performance, and no change in material integrity.

An analysis of the data in the tables shows that all batteries that had been subjected to thermal-vacuum tests at the +55-degree (centigrade) level had to be rejected because of substantially degraded electrical performance. Conversely, the two spare storage batteries, which had not been subjected to thermal-vacuum tests, showed no signs of degraded performance.

4. Power Supply Output Capabilities

The amount of electrical energy available for a given orbit is directly proportional to the sun angle (α angle) and to the percent sun-time of the orbit. Figure 21 shows available-energy curves for 65 percent and 100 percent sun-time orbits. A special set of procedures, entitled "Operational Procedures for Power Supply Monitoring" (Reference 2), was developed to acquaint operator personnel with the use of these curves. This document also contained information designed to familiarize personnel with the procedures to be followed in the event that:

(1) the power consumption of the proposed program would exceed the available power for a given orbit; and

(2) the storage cells failed to recharge to their minimum acceptable level.

E. INFRA-RED HEAT-MAPPING SUBSYSTEM

1. Introduction

The infra-red heat-measuring subsystem was supplied by NASA to measure heat radiation and reflection from earth and its environs in the infra-red through ultraviolet portion of the electromagnetic spectrum. Provisions were included which allowed the system to continuously record the radiation data measured during an orbit on a continuous magnetic tape, and to play back and transmit the recorded data, at an accelerated rate, when commanded by an interrogate pulse from the TV picture subsystem. Telemetric measurements of the temperature, pressure, and calibration of the infra-red (IR) package, and certain time-reference signals were also recorded and transmitted with the radiation data. IR data obtained during the playback periods was bypassed around the tape recorder and transmitted directly to the ground stations at a non-accelerated rate. These direct transmissions were simultaneous with the playback transmissions. Use of this technique insured against loss of radiation data which was measured during the playback period.

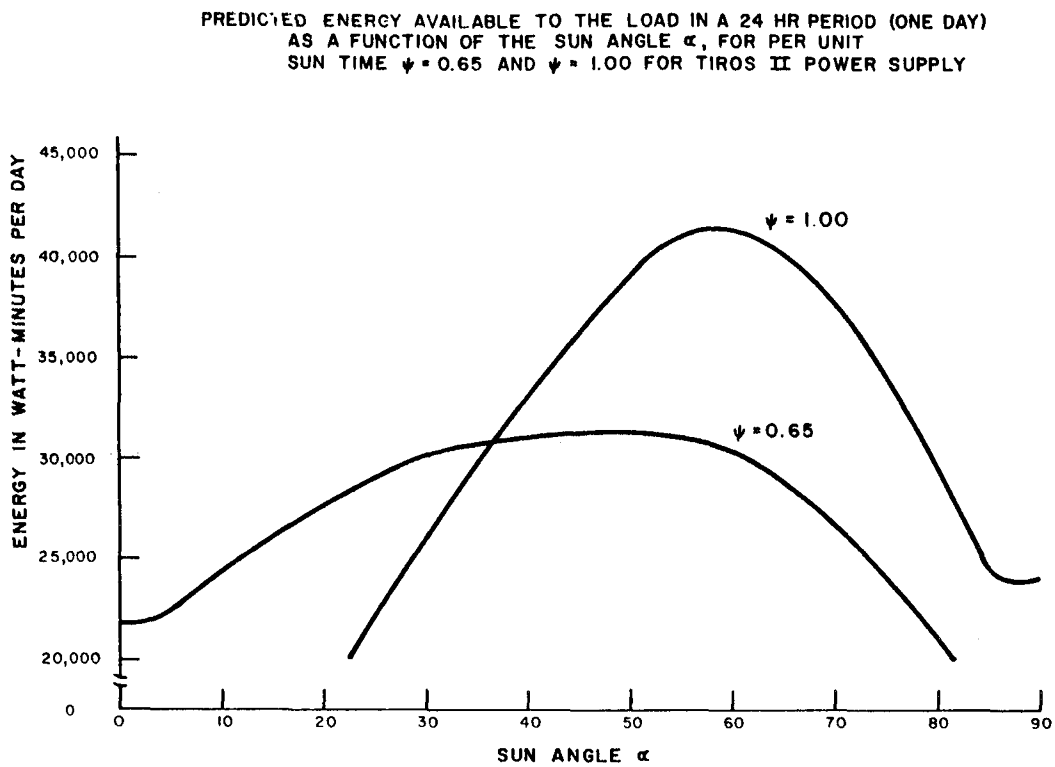


Figure 21. Predicted Power Supply Energy for 65 Percent and 100 Percent Sun-Time Orbits

The operation of the subsystem was controlled by an "interrogate" pulse which was generated in the TV picture subsystem. An infra-red control unit, built by RCA, supplied three pulses of three distinct durations. These pulses provided time references based on the satellite's spin rate, the camera shutter command, and the ground-initiated end-of-tape pulse.

The electrical operating power for the IR subsystem was derived from the satellite's power supply subsystem. The satellite's transmitting-antenna (including the coupling and matching network) was used for transmitting the measured IR data to the ground stations.

The NASA-supplied portion of the IR subsystem essentially consisted of a scanning, five-channel radiometer (FCR) unit; a non-scanning, two-element, widefield radiometer (WFR) unit; a continuous-loop magnetic-tape recorder; and an IR transmitter. Other parts of the subsystem included a commutating switch, subcarrier oscillators, a DC-to-DC converter (power supply), and related electronics. The IR electronics, the IR transmitter, and the tape recorder were contained in a sealed, cylindrical cannister.

The FCR unit consisted of a group of five thermistor-flake bolometers, each of which employed a suitable filter to provide sensitivity to wavelengths in a selected portion of the electromagnetic spectrum between 0.2 and 30 microns. The sensors alternately viewed the earth through an opening in the baseplate and viewed the sky (for reference purposes) through an opening in the side wall of the hat. The planes of the upward (sky) and downward (earth) fields of view were both at a 45-degree angle from the baseplate horizontal reference. A system of prisms and five chopping wheels alternated the sensor's view between the upward and downward directions.

The non-scanning, WCR unit was mounted on the satellite's baseplate and was oriented to view the earth in a downward direction parallel with the spin axis. The unit consisted of one black and one white thermistor-flake bolometer; each bolometer was mounted at the apex of a separate cone, and was identified as either the black cone or the white cone. Initially, provision had been made for the use of a gray cone; however, this cone was not included in the TIROS II satellite.

The channel assignments for the FCR and WFR units were as follows:

Channel	Spectral Response Range (Microns)	Measurement Function
1	5.9 — 7.0	Radiation from earth's troposphere
2	0.6 — 0.8	Visible spectrum for reference
3	0.2 — 5.0	Earth's Albedo
4	7.5 — 30.0	Earth's total emission
5	8.0 — 12.0	Surface or cloud emission
Black Cone	0.2 — 50.0	Earth's total reflective and thermal radiation
White Cone	8.0 — 12.0	Earth's thermal radiation

The five-channel and wide-field radiometer outputs, as well as the telemetry and calibration signals from sensors within the IR package, were applied to six audio-frequency subcarrier oscillators of a self-contained FM/FM transmission system. Time reference signals from the IR control unit were applied to a 7th, tuning-fork controlled, subcarrier oscillator as downward amplitude modulation. This oscillator also served as a frequency reference for calibration of the tape-recorder speed.

2. Functional Description

A functional diagram of the overall infra-red (IR) subsystem, and the associated "common" satellite components, is shown in Figure 22. The modulation and summation network consists of six sub-carrier oscillators, designated channel 1 through channel 5, and a summing network. Channels 1 through 5 of the network are frequency modulated by the outputs of the five-channel radiometer (FCR); the channel 6 oscillator is frequency modulated by the 0.2 to 50μ and the 5 to 50μ IR inputs, and by the telemetry and calibration data inputs. These inputs are sequentially applied to the network by the time-sharing switch. The channel 7 sub-carrier oscillator, a tuning-fork controlled oscillator, provides a standard-frequency source for the tape recorder, and provides a signal to the modulation and summation network which is amplitude modulated with spin-rate, TV camera, and end-of-tape data. The signal from each of the seven sub-carrier oscillators has a bandwidth of 50 cps and is separated from its neighboring signals by 15 cps.

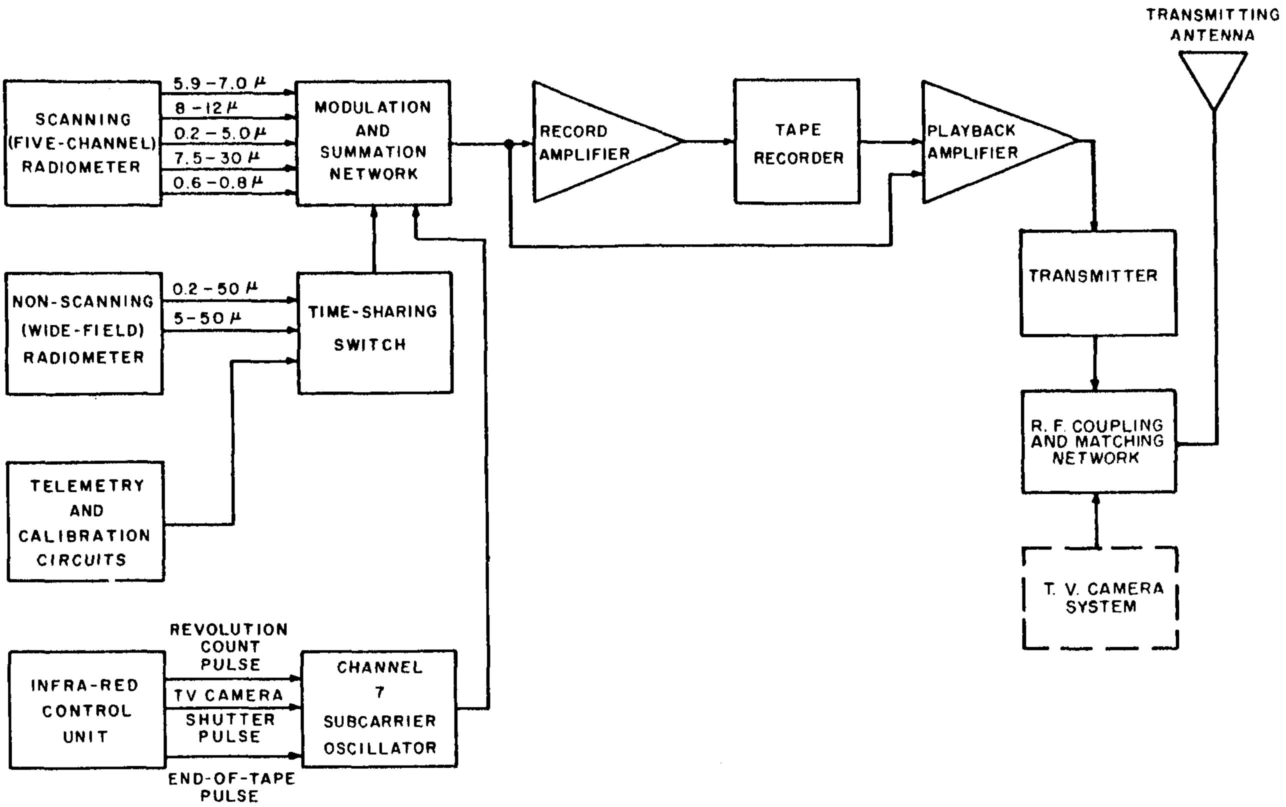


Figure 22. Infra-Red Subsystem, Block Diagram

The outputs of the seven sub-carrier oscillators are united into one complex signal by the summation portion of the modulation and summation network. Except during playback, the complex signal is applied through the record amplifier and recorded on magnetic tape. When the IR package is interrogated and playback begins, the complex signal bypasses the recorder and is applied directly to the playback amplifier. The amplifier applies this direct signal along with the recorded signal, which is being played back at an accelerated rate, to the IR transmitter. The transmitter output is coupled through the coupling and matching network, and radiated by the satellite's transmitting antenna.

The accelerated playback of data (playback occurs 30 times faster than recording) increases the frequencies of the played-back data by a factor of 30. Because of this frequency multiplication the lowest played-back frequency is 100 cps x 30, or 3000 cps, and is easily distinguishable from even the highest direct frequency which is only 410 cps.

3. IR Electronics

a. Functional Operation

The IR electronics system was basically an FM/FM telemetry system that included a tape recording device for storing the data gathered by the satellite and for playing back that data when so commanded. Figure 23 is the block diagram for the IR electronics.

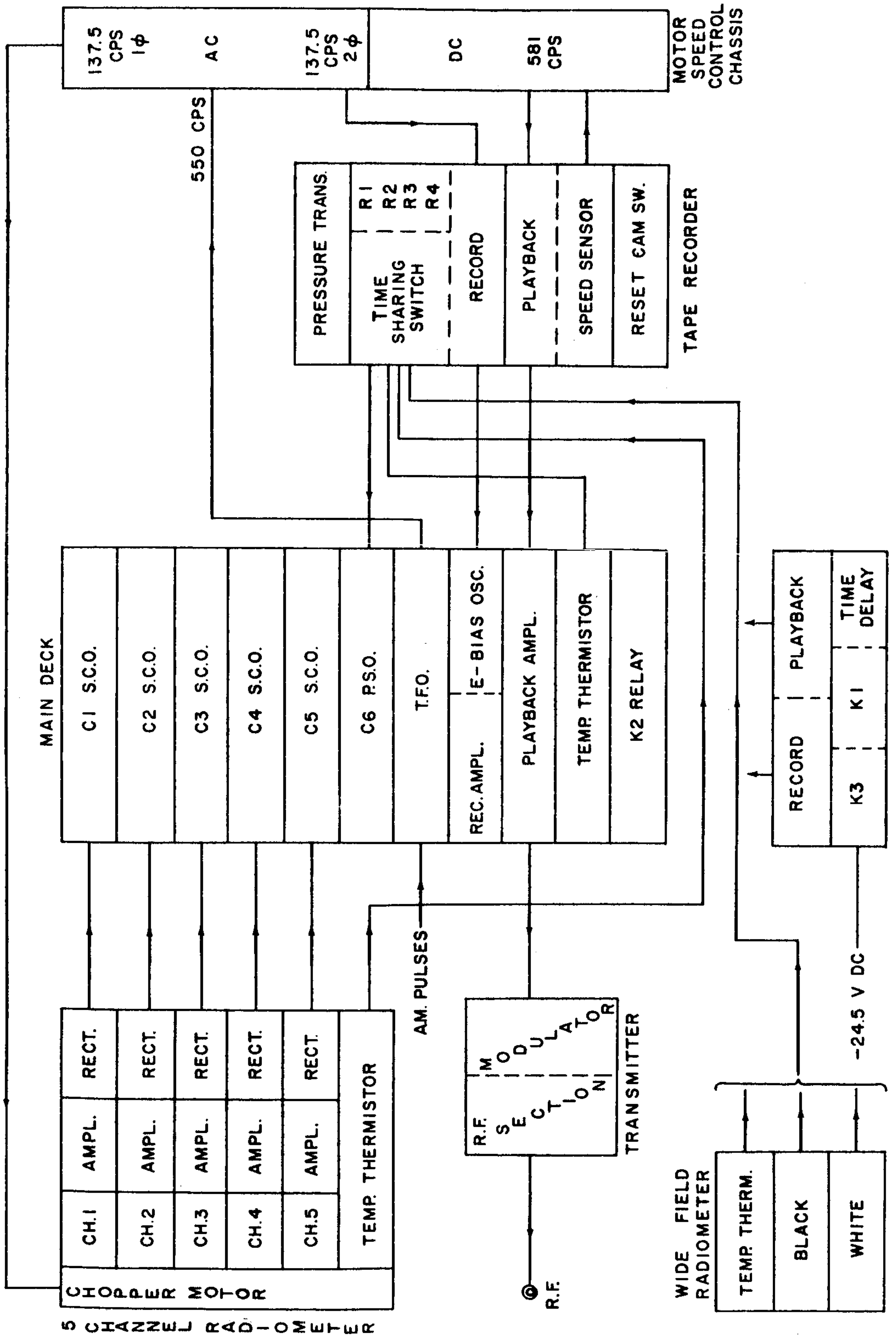


Figure 23. IR Electronics, Block Diagram

The components that comprise the IR electronics are the main deck, the DC-to-DC converter, the tape recorder, the motor speed-control chassis, and the RF transmitter.

Figure 24 is the data flow diagram for the IR heat-mapping subsystem. The outputs of the scanning radiometer are balanced, push-pull, d-c potentials whose amplitudes can vary from approximately ±0.2-volt d-c to ±6-volts d-c. (The ±0.2-volt level represents the lowest noise level output that can be expected from the radiometer, while the ±6-volt level represents the saturation output level.) The outputs from the radiometer shift the frequency of the sub-carrier oscillators by an amount which is directly the level of the detected IR energy. The frequency ranges of the five related sub-carrier oscillators are shown in their respective blocks in Figure 24.

Inputs to the channel 6 sub-carrier oscillator (SCO) are controlled by the time sharing switch. The switch, consisting of three banks of cam-actuated micro-switches, supplies a format of 40 information bits to the SCO during each four-minute interval. These 40 information bits are derived from the ten inputs listed in Table 5; the format of the bits is shown in Figure 25.

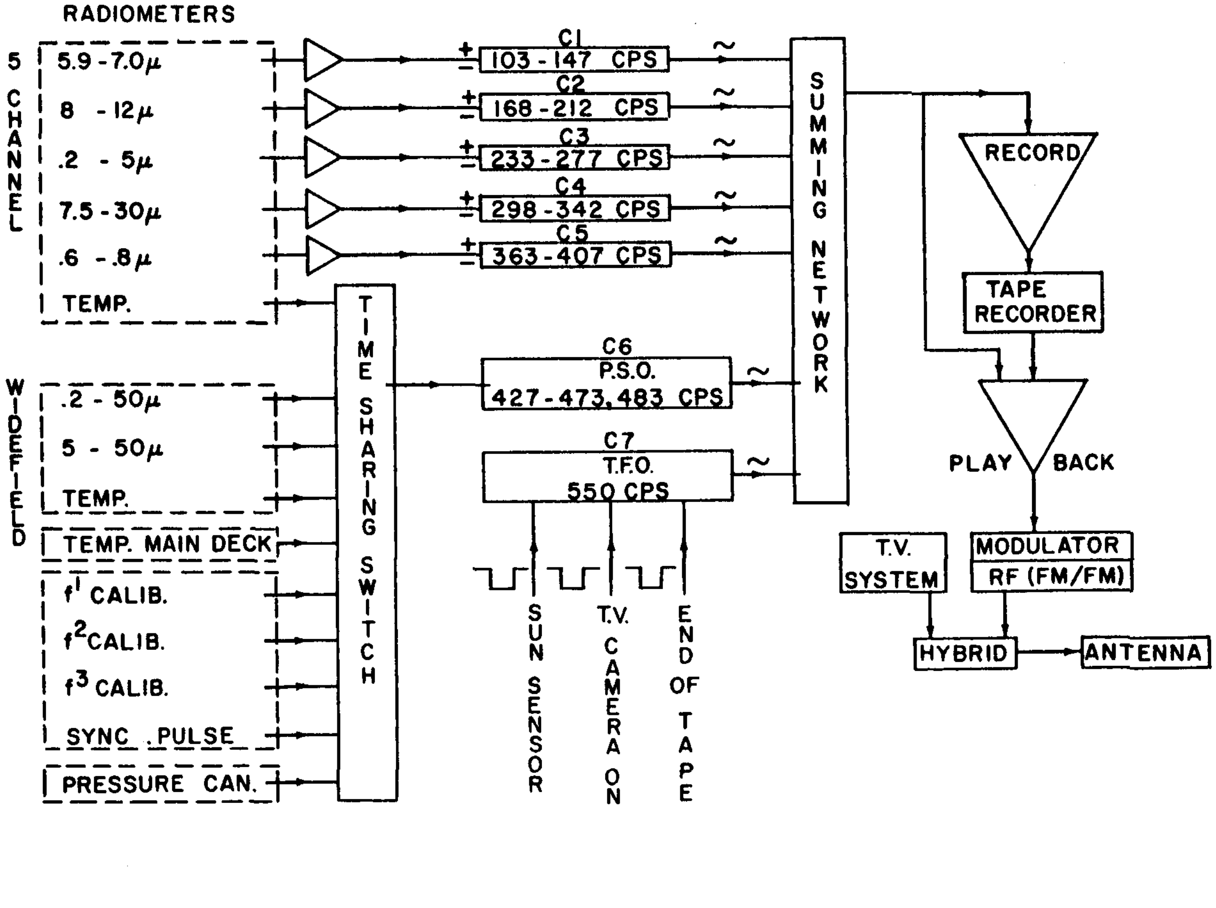


Figure 24. IR Electronics, Data Flow Diagram

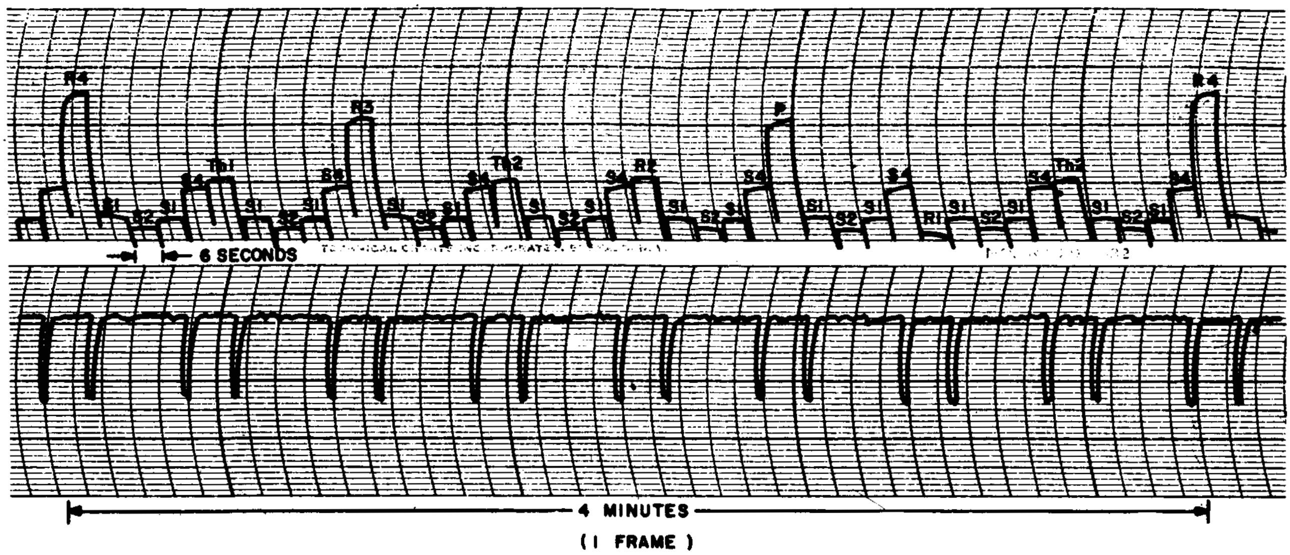


Figure 25. Format of Output from IR Time-Sharing Switch

TABLE 5. INPUTS TO TIME SHARING SWITCH

Reference Designation	Identification
Th 1	Thermistor which monitors temperature of main deck electronics
Th 2	Thermistor which provides reference temperature of scanning radiometer housing
S	Thermistor in black cone of wide field radiometer (WFR)
S_2	Thermistor in white cone of WFR
S_4	Thermistor which provides reference temperature of WFR housing
R_1	0 percent channel 6 calibration frequency (427 cps)
R_2	50 percent channel 6 calibration frequency (450 cps)
R_3	100 percent channel 6 calibration frequency (473 cps)
R_4	Synchronizing frequency calibration (483 cps)
P	Pressure transducer which monitors pressure inside canister

The channel 6 SCO is a phase-shift oscillator whose frequency is a function of the resistance of its frequency determining element. The resistance of this element is controlled by the time sharing switch. The resistance values used to produce the normal FM frequency range of 427 cps to 473 cps are between 250 ohms and 1250 ohms. A resistance value of 1400 ohms is used to produce the 483-cps, synchronizing-frequency, output of the oscillator.

The channel 7 SCO, a tuning-fork controlled oscillator operating at 550 cps, provides two outputs. One output is a CW signal which serves as a standard-frequency for regulating the output frequency of the a-c motor section of the speed-control circuit. The second output is amplitude modulated by the spin-rate, camera-source, and end-of-tape pulses. This signal is fed to the summing network.

The summing network consists of the series resistors in the output of each SCO and a common summing (terminating) resistor which serves as the input resistor for the record amplifier. The summing network also contains a summing resistor for the playback amplifier so that the composite data signal can be fed directly to that unit when the tape recorder is playing back the recorded information. This ensures that current IR data will not be lost during playback of stored data.

During the recording cycle the compositie signal from the summing network is fed to the tape recorder via the record amplifier. An 8-kc erase oscillator is included in the record system to clean the tape prior to each recording operation. The tape recorder records from a 137.5-cps synchronous power source at a rate of 0.4 inches-per-second. To accommodate this recording rate during the entire 100-minute orbit period, the recorder was equipped with a 200-foot continuous tape.

During playback the composite signal is picked-off the tape and fed to the playback amplifier. The playback speed is 30 times the record speed. Therefore, the composite signal frequencies are multiplied by a factor of 30 (i.e. 100 cps on record becomes 3000 cps on playback). Also during playback, the IR data that is being currently sensed is fed directly from the summing network to the playback amplifier. Since the frequencies of the played-back data are 30 times those of the current data, no difficulties are encountered in separating the data at the ground stations.

The playback amplifier furnishes the necessary modulation input level for the RF transmitter modulator. The FM output of the transmitter is fed through the RF transmission system which is common to all components of the TIROS satellite.

The a-c section of the motor-speed control provides a 137.5-cps, 1-phase, power source for the chopper motor in the scanning radiometer, and a 137.5-cps, 2-phase, power source for the record motor in the tape recorder. The 137.5-cps frequency for the power source is maintained by use of the 550-cps standard-frequency input from the channel 7 SCO.

The d-c section of the motor-speed control chassis generates 16-volt d-c power to drive the playback motor in the tape recorder. A speed control a-c signal, with a nominal frequency of 585 cps, is generated by a small alternator attached to the shaft of the d-c motor. This a-c signal is fed to the d-c motor electronics as a correction voltage that holds the motor-speed constant (within ±1 percent) over the specified temperature range.

The DC-to-DC converter, or record power supply, remains on as long as the -24.5 volt d-c satellite power source is operative. The playback supply comes on only during the satellite's playback sequence.

b. Interrogation Sequence

Figure 26 shows the circuitry that controls the playback and record sequences of the IR subsystem. Upon conclusion of the 28-second warm-up period for a TV system playback sequence, an interrogate pulse is generated by the satellite's auxiliary control unit and applied to the IR interrogate relay. This action starts the IR playback sequence.

When the interrogate relay energizes, 24.5-volts d-c is applied to relay K3, causing that relay to "set." The "set" contacts of K3 connect the power source to the transmitter filament power supply (to initiate the warm-up period) and to the 25-second, time-delay circuit.

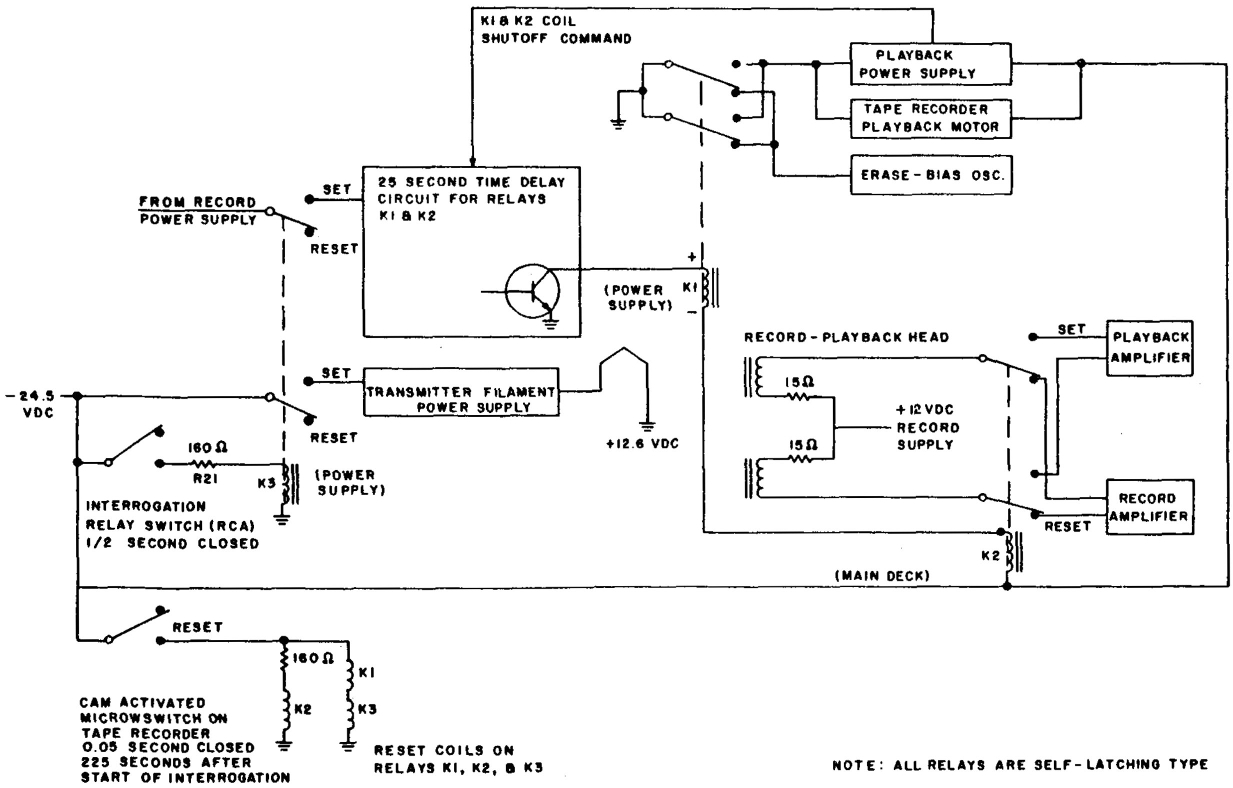


Figure 26. Interrogation-Sequence Control Circuits, Block Diagram

After 25-seconds the time-delay circuit energizes relays K1 and K2. Relay K2 switches the tape recorder's record-playback head from the record amplifier to the playback amplifier. Relay K1 de-energizes the erase-bias oscillator, and applies power to the playback power supply and the playback drive motor. When in operation the playback motor de-couples the record motor by activating a clutch mechanism. The playback power supply energizes the playback amplifier and furnishes a shut-off command to the time-delay circuit which then removes the "set" current from the relay coils. However, the relays are of the self-latching type and remain in their "set" positions.

After 200 seconds (225 seconds including warm-up) of playback operation, a microswitch on the tape recorder is momentarily activated to energize the "reset" coils on relays K1, K2, and K3. When "reset," these relays stop the playback sequence and return the subsystem to the record condition.

4. IR Control

a. General

The IR control unit was added to the TIROS II satellite to provide the three time and events signals required by the NASA infra-red experiment. Although two of these pulses were already available in the satellite's TV subsystem and the third was to be transmitted from the CDA stations, the characteristics of these signals were different from those required for inputs to the IR experiment. Accordingly, an IR control unit was evolved that would shape and standardize the inputs to the IR experiment. The design of this unit incorporated circuits which had been used and proven in other components of the TIROS satellite.

b. Functional Description

The logic and schematic diagrams of the IR control unit are shown in Figures 27 and 28§ respectively. Basically the unit consisted of three one-shot multivibrator circuits. One circuit was triggered by the "J" tone from the CDA station to provide a 1.0-second end-of-tape pulse; the second and third multivibrator circuits were triggered by inputs from the TV subsystem to provide spin-rate and camera-source pulses having durations of 0.5 second and 1.5 seconds, respectively.

The end-of-tape output marks the IR tape at a "known-time" and thus serves as a real-time mark during tape playback. This pulse is initiated from the interrogating CDA station by means of a "J" command tone. The tone "J" command, sent during the playback sequence of the program, is separated from the command carrier and applied to AND gates Q1 and Q2 as an audio frequency. The AND gates, audio-frequency emitter followers, are enabled only during playback 1 or playback 2. This prevents spurious pulses, which might be received during a different program sequence or during other portions of the satellite's orbit, from reaching the "J" tone filter and thus minimizes the possibility of spurious end-of-tape pulses.

§ This illustration is printed on a foldout page located at the rear of this Section.

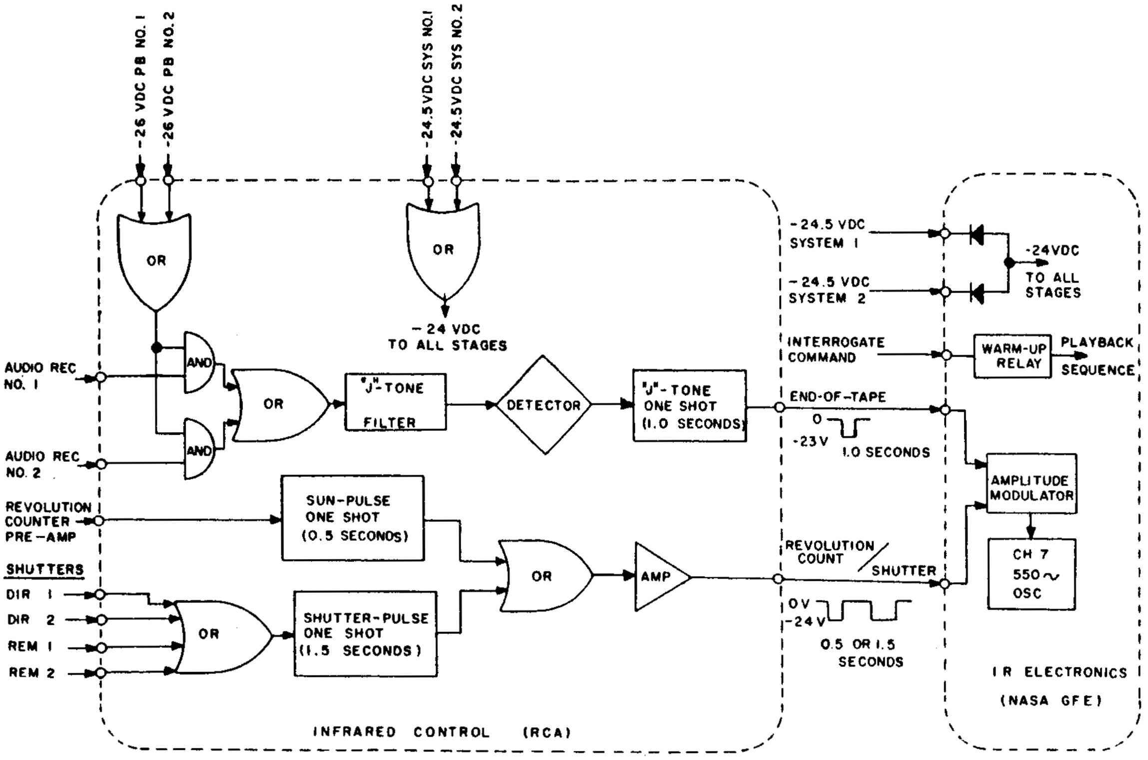


Figure 27. Infra-Red Control Unit, Logic Diagram

The "J" tone filter passes the "J" command tone while attenuating any other command tones that might be present while the AND gates are enabled. After several cycles of the "J" tone have been received, the output of the filter builds sufficiently to turn on the detector. The detector output is filtered and differentiated, and then used to trigger the 1.0-second multivibrator.

The one-shot multivibrator is of the complimentary NPN-PNP type with both transistors turned off during the "off" portion of the output. Since the multivibrator is triggered only once per interrogated orbit, the use of this "both off" technique results in a considerable power savings. The multivibrator is triggered by the positive spike of the differentiated output from the detector. Multivibrator action produces a positive-going waveform at the base of transistor Q5. Thermistor RT1, in the base circuit of transistor Q4 compensates for the temperature coefficient of timing capacitor C8 and for variations of the emitter-base threshold voltage for the transistors. The duration of the output pulse is held to 1.0 second ±5 percent over the temperature range of -10 to +60 degrees centigrade.

The 1.5-second and the 0.5-second one-shot multivibrators are very similar in operation to the circuit described. The point selected for triggering depends upon the polarity of the available source.

The 1.5-second multivibrator provides one output pulse for each camera-shutter operation. Since each TV camera system has a direct and remote mode, the circuit is designed to accept any one of four inputs. The "direct" commands are differentiated and then applied to the 1.5-second multivibrator through the diode OR gate. The "remote" shutter commands can occur either simultaneously or separately. These signals are also applied through the OR gate to the multivibrator.

The 0.5-second one-shot multivibrator is triggered by the output from one of the north-indicator sensors located about the periphery of the satellite. The positive-going output of the sensor is preamplified before being applied to the IR control unit. This pre-amplified signal is coupled through diode CR16 and triggers transistor Q10, the NPN transistor of the 0.5-second multivibrator. The one-shot multivibrator is triggered once every 4 to 6 seconds, depending upon the satellite's spin rate.

The outputs of the 0.5-second and 1.5-second multivibrators are negative-going pulses whose periods are held to within ±5 percent of their respective nominal durations. A thermistor-resistor combination in each multivibrator ensures pulse-width stability over the -10 to +60 degrees centigrade temperature range. The output from either the 1.5-second or the 0.5-second multivibrator can "turn on" amplifier Q11. This amplifier provides a low impedance output with adequate load isolation.

The interrogate command, which starts the IR playback sequence, is generated in the auxiliary control unit each time that a playback command (PB1 or PB2) is received. Although the interrogate command presently has no function within the IR control unit, it may be used in future units as an enabling trigger for a gate in the end-of-tape pulse circuit. An interrogate-command monitoring signal is provided on the IR control chassis to facilitate checking the sequencing of the other IR commands.

c. Testing

The IR control unit received initial breadboard tests over the required temperature range. A non-flight engineering model was constructed for a layout check and was wired into the prototype satellite for a system check. The input OR gates for the direct shutter-pulse trigger were changed from d-c to a-c coupled to eliminate feedback from the non-operating camera control. The "J" tone filter was found to "ring" on the second harmonic of the set pulses. A loading resistor at the filter output and a reduction in threshold of the one-shot eliminated the tendency for the one-shot to trigger on the ringing. RF interference from the TV transmitter was found to occasionally trigger the shutter pulse 1.5-second one-shot. A small resistor-capacitor filter in the base lead of Q7 bypassed the unwanted pickup.

F. MAGNETIC ATTITUDE CONTROL SUBSYSTEM

1. Introduction

The magnetic attitude control subsystem was one of the major additions to the TIROS II satellite. This subsystem afforded control over the path of the satellite's spin-axis, and thus assured optimum operation of the IR experiment, the TV subsystem, and the solar cell power supply. The need for the subsystem was established as a result of the analyses of spin-axis motion, which were made during the operational evaluation of the TIROS I system. These analyses indicated that the differences between the predicted and observed spin-axis motion was caused primarily by the torque resulting from the interaction of the satellite's magnetic dipole moment and the earth's magnetic field.

Further analyses of the observed motion of the spin axis lead to the conclusion that the TIROS I satellite's net dipole moment was equivalent to a current of 0.9 ampere flowing in a plane normal to the spin-axis and enclosing an area of one meter squared. Although the maximum torque caused by a dipole moment of 0.9 ampere-turns-meter^2 was only 1.6×10^{-5} ft-lbs., this torque was sufficient to cause the spin-axis to precess at a rate of approximately 4 degrees-per-day.

The primary steps in providing for attitude control of the TIROS II satellite were:

(1) the reduction of the residual dipole moment in order to decrease the rate of unwanted precession; and

(2) the development of a means by which known dipole moments could be programmed into the satellite in order to induce a desired precession.

Before the residual dipole moment of the TIROS II satellite could be reduced, the strength and direction of the dipole moment for each of the satellite's operational modes had to be measured. These measurements were made by using the test apparatus shown in Figure 29. The outer sphere of the apparatus consisted of two specially wound spherical coils. One coil was used to measure the satellite's dipole moment; the second coil was used to cancel the earth's magnetic field so that induced eddy currents, and dipole moment noise, would be held to a minimum. (A detailed description of the test apparatus and the test procedure are presented elsewhere in this section of the report.)

Once the satellite's residual magnetic dipole moments were established, a small permanent magnet was added to the satellite to effectively cancel the measured dipoles. The dipole moment was then remeasured for all modes of satellite operation to ensure that its average was close to zero.

The device selected for allowing dipole moments to be programmed into the satellite was a coil of wire wrapped about the periphery of the satellite. The current through this coil was controllable from the TIROS ground stations so that eleven different dipole moments could be introduced. The values of these dipole moments ranged from +3 to -3 ampere-turns-meter^2.

In order to minimize the power that would be consumed by the attitude control coil, the number of turns of wire was limited to 250. The coil was made from aluminum wire rather than copper wire; this resulted in a weight savings of one-half pound. In order to induce the desired dipole moments, it was necessary to provide for current-flow in both the positive and the negative directions. Since the only available voltages were negative in respect to the ground, neither end of the attitude control coil could be permanently grounded.

Figure 29. Magnetic Dipole Moment Test Apparatus

The electronics for the magnetic attitude control was basically a stepping switch which received its control inputs from the auxiliary control electronics. Stepping of the switch was achieved whenever the attitude command tone, initiated by the ground station, was transmitted for the required interval of time. A position-readout provision was included so that the position of the switch could be telemetered to the ground station. The position readout took place each time the switch was stepped. This position readout could be achieved without changing the switch position (current in the coil) by terminating the control tone in less than the required interval.

2. Attitude Control Electronics

a. General

The electronics for the magnetic attitude control had two functions: First, it provided a means for changing the current in the attitude control coil; Second, it afforded a means of telemetry readout of the position of the attitude control switch. The design of attitude control electronics was greatly influenced by the compressed time schedule. Whenever possible, circuits were used that had already been proven in other applications within the TIROS satellite.

Initial studies of the overall attitude control functions indicated that attitude-control programming would not be required at frequent intervals. Therefore, it was concluded that a stepping switch, controlled by a single control pulse, would provide adequate reliability. The use of this system permitted a much simpler circuit design than would have been possible if a binary coded system had been employed.

A time delay circuit was included in the attitude control electronics. The delay circuit prevented the attitude control switch from advancing unless the command tone was received for a given interval without interruption. This time delay afforded a means by which the position of the attitude control switch, and hence the level of the current flowing in the coil, could be telemetered to the ground station without resulting in stepping action of the switch.

b. Functional Description

Figure 30 is a block diagram of the attitude control electronics. Operating voltage, -26.5 volts d-c, is applied to the attitude control electronics only during a playback or direct camera sequence. The operating voltage is applied, from control relays in the camera system that is being programmed, approximately 28 seconds after the start of the sequence.

The audio control tones, initiated by the ground station, are applied to the attitude control electronics via the control unit of the camera system in operation. The inputs are applied to OR gate 1 through either emitter follower 1 or emitter follower 2. The output of the OR gate is applied to the 4-percent bandpass filter. This filter passes the attitude command frequency (Tone C) while greatly attenuating the other command frequencies. Upon receipt of the tone C input, the relay driver energizes either relay K1 or K2,

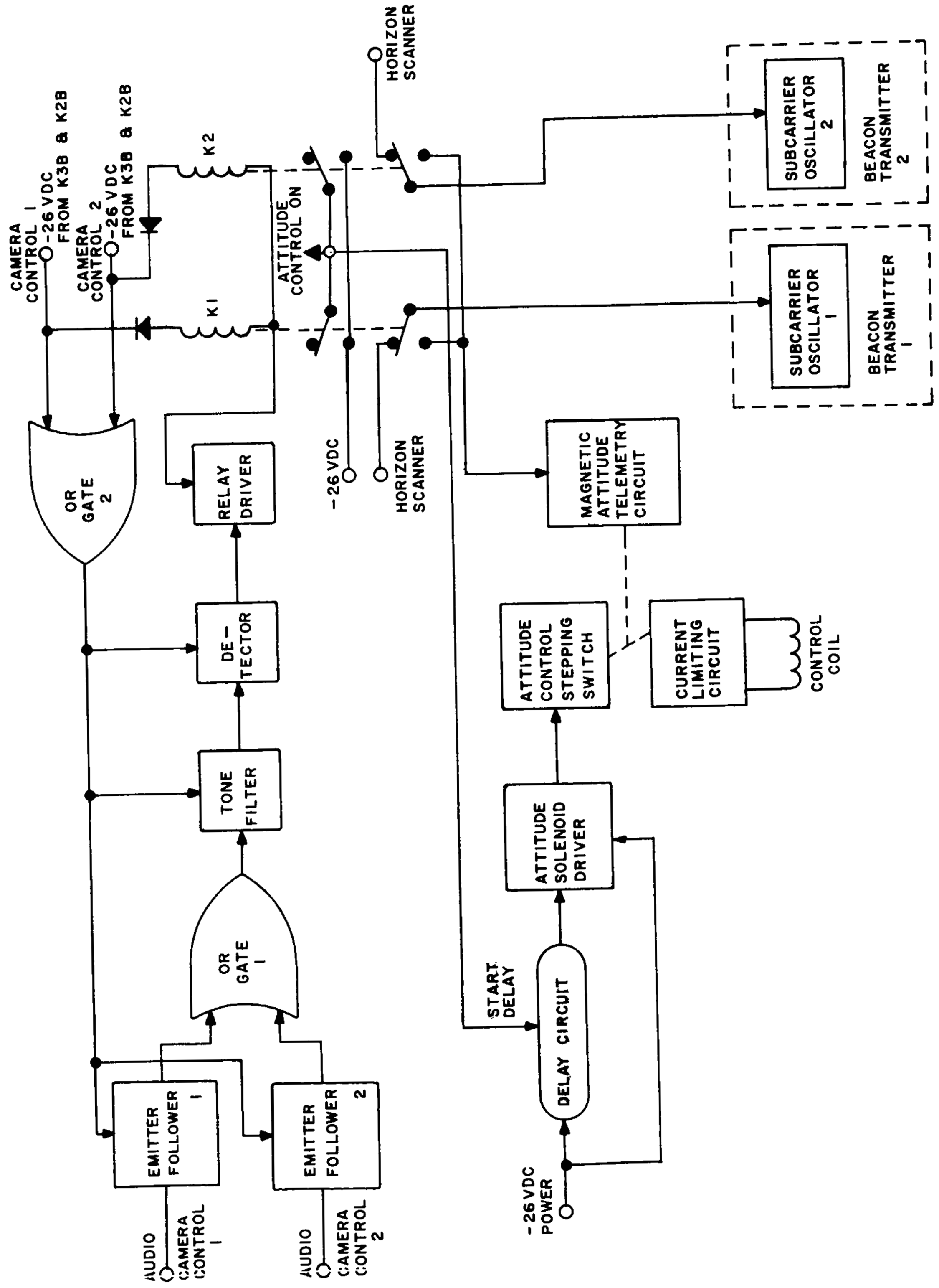


Figure 30. Attitude Control Electronics, Block Diagram

depending upon which camera system is in use. When either relay picks-up, the attitude telemetry circuit is connected to one of the beacon transmitters, and the -26 volts d-c is applied to the delay circuit.

The attitude telemetry circuit is basically a voltage divider network. The output of the network is a d-c voltage whose level is proportional to the position of the attitude control switch (current through the attitude control coil). The delay line prevents the attitude control switch from stepping until the tone C command has been received for the required interval. This delay line permits the position of the attitude switch to be monitored without causing the switch to advance.

The normal vibration and thermal-vacuum tests were performed on the prototype and flight model units. The units met the design specifications for pulse-width and pulse-amplitude over the required temperature range in vacuum.

If the tone C input is present for the required interval, the attitude stepping switch advances one position and changes the current through the control coil by changing the value of resistance in series with it. Since only one voltage polarity is available, the stepping switch is wired so that when the switch steps past the "home" position the ground and power sides of the coil are reversed. The following tabulation lists the dipole moment which is imparted to the satellite in each position of the attitude control stepping switch, as well as the level of telemetry voltage used to represent each position of the switch. The schematic diagram of the attitude control electronics is shown in Figure 31§.

Switch Position	Dipole Moment (Ampere-Turns-Meter^2)	Telemetry Voltage (Volts D-C)
0	0	0
1	-2.84	-0.25
2	-1.35	-0.75
3	-1.02	-1.25
4	-0.70	-1.75
5	-0.35	-2.25
6	0	0
7	+2.9	-2.5
8	+1.35	-2
9	+1.02	-1.5
10	+0.70	-1
11	+0.35	-0.5

§ This illustration is printed on a foldout page located at the rear of this Section.

3. Determination of the Satellite's Dipole Moment

a. Experimental Apparatus*

The apparatus used for determining the satellite's dipole moment is shown in Figure 29. Basically, this apparatus consists of a gimballed mount and a 100-inch sphere. The mount, which has three degrees of freedom, is cantilevered so that its center is coincident with the center of the 100-inch sphere. The mount is driven only along one axis; the other two axes are locked into whatever position is desired. This arrangement of the mount allows the unit under test to be spun about any arbitrary axis at a speed which is continuously variable between zero and 120 rpm.

The inclination of the earth's magnetic field at the latitude of RCA's facility near Princeton, New Jersey, is approximately 72 degrees when measured from the horizontal. In order to provide cancellation of the earth's magnetic field within the sphere, the specially wound spherical coils had to make an angle of 18 degrees with the vertical. The great circle (of the sphere) that had this 18-degree inclination was chosen as the separation plane to facilitate sphere removal and to allow access to the gimbal mount.

The sphere is constructed almost entirely of rolled aluminum extrusions; the only exceptions being the polar caps. These caps are machined disks. The meridian ribs are channel members 3/4-inch square with 1/8-inch wall thickness. The equatorial mating members are 2-inch angle sections 1/8-inch thick. The overall sphere weighs less than 100 pounds and, with the addition of 80 pounds of No. 26 copper wire, supports its own weight with negligible deflection when resting on one polar cap.

The gimbal structure is cantilevered primarily to achieve a high degree of accessibility for sphere removal and test body insertion. The gimbal is a 4-inch aluminum H section with mitered, welded corners. The inner gimbal carries all the lighting fixtures (required for simulating orbital day) arranged in three groups. A flat plate, 40 inches in diameter, mounting fifty-two 150-watt bulbs provides near-uniform illumination for the top section of TIROS. Two identical rings, mounting eighteen 300-watt bulbs each, are provided on either side of TIROS to illuminate its sides. Only half of these lights, 180 degrees of arc, are illuminated at any one time. This grouping of lights is rotated electrically at 12 rpm to simulate the sun's illumination on the sides of a rotating satellite. This is accomplished by a motor-driven bank of 18 cam-operated microswitches.

Power lines for these lights, as well as other control wires, pass through heavy-duty silver slip rings on the main support shaft. The gimbal drive system is by belt from a 1/3-hp, variable speed, d-c motor.

Auxiliary test apparatus included a Krohn Hite, Model 330M, Ultra-Low Frequency Band Pass Filter, and a Tektronix Type 532 oscilloscope equipped with a Type 53/54E low frequency preamplifier. This equipment was required for measuring the currents induced in the sphere's measurement coil. The signal that resulted from the induced currents had a frequency equal to the frequency of rotation of the satellite within the measuring

*The theoretical considerations involved in the development and the use of this apparatus are described in Appendix B of this report.

coils (approximately 1 cps). The magnitude of this signal was usually under 5 milliwatts peak-to-peak. The 60-cycle noise "picked-up" by the coil was many times greater than the signal, as was the 2-cps signal caused by induced eddy currents. In order to reduce the magnitude of these unwanted signals, the output of the measuring coil was applied through the band-pass filter before being applied to the oscilloscope for measurement.

The upper and lower cut-off frequencies of the filter were set at the frequency of the satellite's rotation; this produced a narrow frequency-response band that was 2 db down at the signal frequency and which dropped at the rate of 24 db-per-octave on either side of the signal frequency.

The oscilloscope was adjusted to sweep upon receipt of a signal from the rotating satellite. A Polaroid oscilloscope camera was used to record the oscilloscope display.

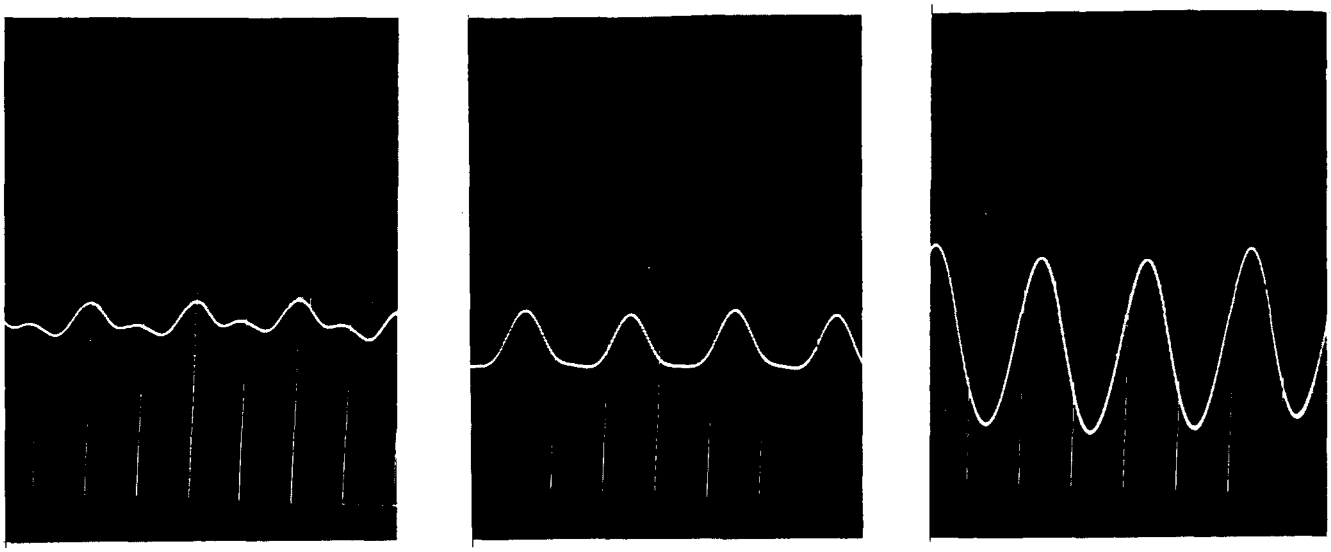
b. Calibration of Apparatus

Before the satellite was tested, the response of the measuring system and the magnetic dipole of the rotating experimental structure had to be determined. This was accomplished with the aid of two calibration coils which were mounted on the spinning part of the equipment. The axis of one of the coils was parallel to the spin axis of the satellite; the other coil axis was perpendicular to the spin axis. Current was supplied to these coils from external power supplies through the slip rings.

The rotating structure, with the satellite, was spun at the test frequency of 1 cps. With no current through either of the calibrating coils or through the cancellation coil, the measuring coil registered a high-amplitude 2-cps signal, and a low amplitude 1-cps signal. The Krohn Hite filter was set to pass only the 1-cps signal and to filter out the signal components of frequencies higher than 2 cps. The 2-cps signal, which was produced by eddy-currents was reduced by cancelling out the field inside the sphere. This was done by passing a current through the cancellation sphere and observing the induced signal.

Once the 2-cps signal was reduced to a minimum, the two calibration coils were used to determine the net magnetic dipole of the rotating structure and to determine the sensitivity of the testing equipment. The former was accomplished by adjusting the current through the two coils until the first harmonic was reduced to zero. When this was done, the dipole created by the calibration coils was just equal and opposite to that of the rotating machine.

In order to test the response of the measuring equipment, the current through the calibration coil at right angles to the spin axis was kept constant, while the current through the other calibration coil was varied. The total area of the latter coil was 1.46 meter^2. From pictures similar to those shown in Figure 32, it was determined that a magnetic dipole of 1 ampere-turns-meter^2 would produce a signal of 2.04 millivolts peak-to-peak; that is, the circuit sensitivity was 0.492 ampere-turns-meter^2/millivolt. This value was checked for each phase of the test procedure, and was found to remain constant.



a

Oscilloscope Display With Calibrating Dipole of +0.146 Ampere-Turns-Meter^2

b

Oscilloscope Display With Calibrating Dipole of -0.292 Ampere-Turns-Meter^2

c

Oscilloscope Display With Calibrating Dipole of -0.89 Ampere-Turns-Meter^2

Figure 32. Magnetic-Dipole Moment, Calibration Oscilloscope Patterns

c. Measurement Procedure

The satellite was mounted within the test sphere and rotated at one revolution-per-second. The band-pass filter was centered at 1-cps; the calibration coils were connected into the test circuitry; and the cancellation-coil current was adjusted to reduce the second-harmonic noise to a minimum. The oscilloscope was adjusted to sweep when it received an input from measurement coil so that the phase of the induced voltage, relative to the rotation of the satellite, could be determined.

After the calibration was checked, the net dipole moment of the satellite was determined using two different methods. The first method involved taking a picture of the oscilloscope trace and using the calibration and phase information to compute the component of the magnetic dipole along the spin-axis as well as the component perpendicular to it. The second method involved cancelling out the components of the dipole moment by passing current through the two calibration coils. Usually, both methods were used when power was not applied to the satellite, or when the satellite was in the "nighttime" standby mode of operation.

Only the dipole moment along the satellite's spin axis was of interest when the satellite was in nighttime standby. Therefore, when the first method was used to check the nighttime dipole, a current was made to flow in one of the calibration coils in order to cancel out the perpendicular component of the dipole. In order to determine the daytime dipole moment, the test lights were turned on to simulate the sun and the currents (signals) induced in the measuring coil were recorded by the oscilloscope camera.

Figure 33 depicts the differences between the daytime and nighttime dipole moments of the TIROS II satellite. The figure shows that the daytime current loops resulted in one dipole moment parallel to the spin axis and one perpendicular to the spin axis. Since the time during which the satellite could be kept running without recharging was limited, no attempt was made to cancel the perpendicular moment through use of the calibration coils. Other modes of satellite operation for which the dipole moment was checked included:

(1) Direct picture taking and transmitting with alternate cameras

(2) Remote picture taking and storage with alternate cameras

(3) Playback and transmission of the stored information of each camera during day and night conditions

Two complete series of tests were necessary for each satellite. After the first series of tests, a small magnet, which had the same strength dipole as the average satellite dipole, was placed on the satellite in such a way as to cancel out the dipole moment. The satellite was then retested with the magnet in place.

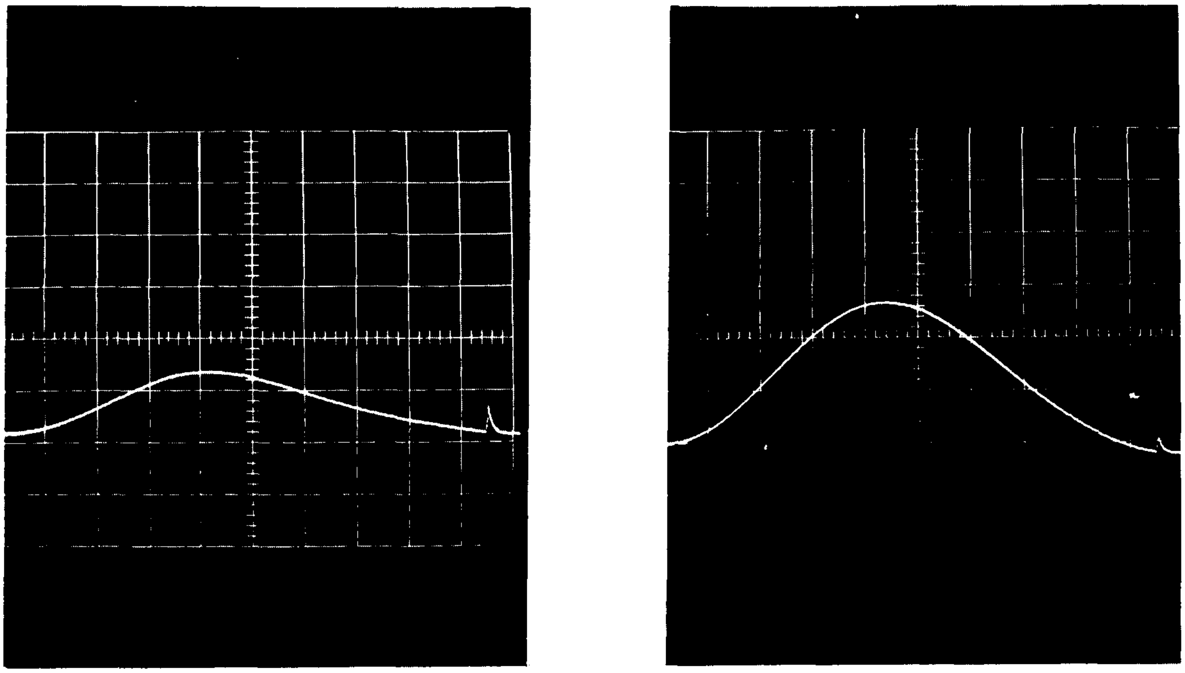
d. Results

Tests were run on three different TIROS II satellites. The results of these tests indicated that all three of the satellites had magnetic dipole moments of the same order of magnitude as had been calculated for TIROS I. When the TIROS II satellites were tested with power off, a large percentage of their magnetic dipole moment remained. (This showed that magnetic material had had an appreciable effect on the motion of the TIROS I satellite.)

The most important mode of operation in terms of contributing to the average dipole moment was the standby mode. It was determined that the nighttime magnetic dipole caused by current loops was small (less than 0.10 ampere-turns-meter^2), while for daytime operation it was as large as 0.35 ampere-turns-meter^2. This daytime variation was attributed to the battery charging current from the solar cells. Other operational modes differed from the standby mode by as much as 60 percent. Although the other operational modes did not greatly influence the average dipole moment under normal operating conditions, it was considered possible that an unexpected method of operation might cause some mode other than standby to be of significance.

The basic uncompensated, standby-mode, dipole moment of the TIROS II satellite that was launched on November 23, 1960, was 0.97 ampere-turns-meter^2 for orbital night conditions and 1.39 ampere-turns-meter^2 for orbital day conditions. Prior to launch these basic values were reduced to -0.31 and +0.10 ampere-turns-meter^2, respectively, by the addition of the small bar magnet.

During the tests, the magnetic control coil was calibrated. The tests showed that the presence of the small amount of ferromagnetic material in the satellite did not measurably change the effectiveness of the coil. Thus, the magnetic dipole of the control coil was simply $\mu_0 IA$.



a. Nighttime b. Daytime

Figure 33. Standby Dipole Moments of Satellite

The following tabulation lists the magnetic moments of the TIROS II satellite model F-2 with no current flowing through the control coil. The values listed were measured after a permanent magnet, having a strength of -1.30 ampere-turns-meter^2, had been added to the satellite.

TABLE 6. MEASURED MAGNETIC DIPOLE MOMENTS OF SATELLITE F-2

Operational Mode	Magnetic Dipole Moment (Ampere-Turns-Meter^2)	
	Orbital Day	Orbital Night
Standby	+0.10	-0.31
Remote-Picture taking with both cameras in sequence	+0.42	
Playback-Camera 1	+0.08	-0.53
Playback-Camera 2	+0.05	-0.62
Direct 1	+0.26	
Direct 2	+0.11	

G. ANTENNA SUBSYSTEM

1. General

The satellite antenna subsystem provided a means for the reception of command signals from the CDA station and for the simultaneous radiation of energy from four separate transmitters (two beacon, one IR, and either one of two TV). The subsystem also provided for coupling and matching the receivers and transmitters to the antennas, and for isolating the four active transmitters and the two command receivers.

Basically, the subsystem consisted of a simple dipole antenna for the command receivers, and two crossed-dipole antennas (two frequency) and an associated RF matching and coupling network for the transmitters. Selection of the TV transmitter to be connected to the RF matching and coupling network was regulated by the satellite's programming and control equipment.

2. Requirements

The requirements for the satellite antenna subsystem were:

a. Circularly polarized radiation from the transmitting antennas.

b. A radiation pattern as nearly isotropic as possible, with minimum distortion due to the satellite's shape.

c. Efficient operation in the following frequency bands:

   108 Mc (transmission)

   240 Mc (transmission)

   140 Mc (reception)

d. Simultaneous radiation from four transmitters, two in the 108-Mc band and two in the 240-Mc band.

e. Simultaneous operation of the receiving circuits and the four transmitters listed, with no blocking interference to the receiving system from the satellite transmitters.

f. Mechanical and dimensional characteristics of the satellite antenna subsystem within the mechanical and spatial limitations imposed by the form factor of the satellite, and the limitations imposed by the launching vehicle.

3. Receiving Antenna

The TIROS II receiving antenna, a quarter-wave dipole operating in the 140-Mc band, was identical to the TIROS I receiving antenna. It was fed against the satellite and positioned in the neutral plane of the transmitting antennas so as to provide 40 to 45 db of attenuation between the transmitter and receiver terminals without the use of a filter. The design, the development, and the testing of the receiving antenna are described in Volume IV, the Classified Supplement, of the TIROS I Final Report (Reference 1).

4. Transmitting Antenna System

The transmitting antenna system, consisting of four dipole elements arranged to form two crossed-dipole pairs, was identical to the TIROS I system. The dipole elements in each pair were fed in push-pull, while the pairs were fed in phase quadrature with respect to each other. This feed configuration resulted in a 90-degree phase progression from element-to-element around the system and thus achieved circularly polarized radiation.

Each dipole element consisted of a coaxial sleeve and a rod assembly that were electrically connected to each other at the feed point. The sleeve length was set at 0.25λ in the 240-Mc band, while the rod was allowed to extend beyond the sleeve a distance which raised the terminating resistance of the element from $12.5 + j0$ ohms (with no extension) to $50 - jx$ ohm. The $-jx$ reactance was compensated by adjusting the series inductance derived by the internal coaxial portion of the antenna. The desired feed-point impedance of 50 ohms (non-reactive) was thus achieved for each dipole element in the 240-Mc band.

The physical length of the rod portion was approximately 0.3λ at 108 Mc. The feed-point impedance of the element at 108 Mc, including the effect of the series inductance of the inner portion, measured approximately $150 - j100$ ohms. This impedance was transferred to $50 + j0$ by means of a transformer and stub arrangement in the coupling and matching network.

For a detailed description of the design, development, and testing of the transmitting antenna system, refer to Volume II of the TIROS I Final Report (Reference 1).

5. RF Coupling and Matching Network

a. Introduction

The TIROS II coupling and matching network was basically an improvement of the TIROS I network. Near the conclusion of the TIROS I contract, RCA engineering personnel indicated that, in their opinion, a considerable savings in both the weight and the volume of the network could be achieved if additional development time were available. Accordingly, the TIROS II design efforts were aimed at attaining these savings. A description of the initial development and design of the coupling and matching network is contained in Volume II of the TIROS I Final Report (Reference 1).

Basically, the TIROS I coupling and matching network consisted of six components (two diplexers and four baluns). Each component was mounted on an individual printed circuit board and was interconnected with the other components by means of coaxial cables and BNC connectors. The total weight of the network was 11.5 pounds while its volume was approximately 320 cubic inches.

For the TIROS II network, RCA devised a system which allowed closer spacing between stripline fold-backs and thus allowed more than one component to be printed on a single board. This not only reduced the volume of the printed boards; but, more important, it reduced the number of coaxial cables and connectors, and also lessened the requirements for the mounting brackets and their associated hardware. By using this closer fold-back system, RCA was able to package the coupling and matching network so that it weighed only 2.7 pounds and so that its volume was only 26 cubic inches.

b. Network Requirements

The general requirements of the RF coupling and matching network were as follows:

(1) To provide simultaneous RF coupling to the radiating elements for two 108-Mc band transmitters and two 235-Mc band transmitters while ensuring a minimum "feed-through" between the transmitters.

(2) To provide sufficient isolation between the transmitters operating in the two different frequency bands to prevent interaction between these transmitters.

(3) To divide the energy from each transmitter into four equal signals that were phased so as to produce a circularly polarized field when radiated from the crossed dipole transmitting antennas.

(4) To achieve an impedance match between the radiating elements and the transmitters.

c. Development and Design

Figure 34 is the schematic diagram of the RF coupling and matching network. Development of the circuitry was achieved during the TIROS I project; the primary efforts during the TIROS II program were aimed at repackaging the network to reduce its volume and weight.

During the initial phase of the repackaging effort, RCA conducted studies to determine the minimum allowable stripline fold-back spacing. The results of these studies showed that, for a characteristic impedance of 50 ohms and a board thickness of 1/16 inch (center to outer conductor), the center-to-center dimension of the fold-back could be reduced to 1/4 inch without resulting in a significant amount of mutual coupling. By using this minimum spacing, RCA was able to design the TIROS II coupling and matching network so that one entire frequency section (one diplexer and two baluns) would fit on a single board having length and width dimensions of approximately 9 inches and 11.5 inches. Each board was comprised of two separate plates; each plate consisted of a stripline interconductor that was separated by the copper outer conductor by means of a teflon dielectric.

The board for each frequency section was layed out so that the common points, points B, E, N, and Q of Figure 34, would lie in register when one board was aligned above the other. Electrical connection of these common points was effected by making small holes in the dielectric and outer conductor of each board through which short copper strips could be passed. One end of each copper strip was soldered to an L2 segment of the 235-Mc board while the other end was soldered to the L3 segment of the 108-Mc board. This connection technique is depicted in the cross-sectional view of the coupling and matching network shown in Figure 35.

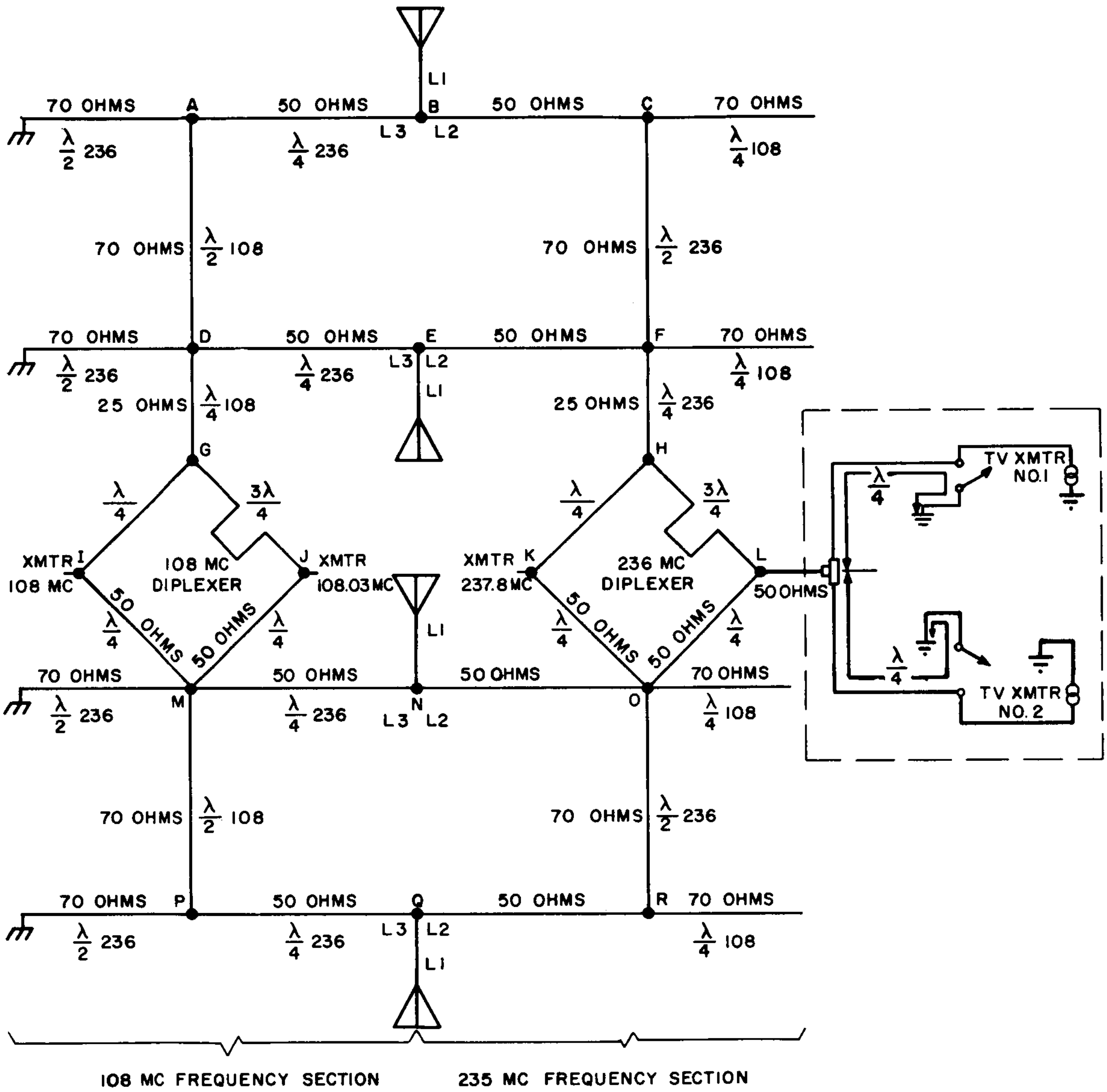


Figure 34. RF Coupling and Matching Network, Schematic Diagram

A BNC chassis connector was mounted at each of the common points to allow for connection of the L1 cables from the dipole elements. BNC chassis connectors were also mounted on each board so that the transmitters could be readily connected to or disconnected from their associated diplexer.

Use of this board-on-board technique permitted the elimination of the interconnecting cables within the network itself. The elimination of the internal cabling resulted in a total transmission line length (cable plus strip-line) of only 47 feet in the TIROS II network as compared to the 60 feet of transmission line required in the TIROS I network. This reduction in total length was reflected in an improvement of the insertion loss figure. The TIROS II insertion loss was between 0.2 and 0.3 db in the 108-Mc section and equal to or less than 0.5 db in the 235-Mc section. The insertion losses for TIROS I were approximately 0.5 db and 0.75 db at 108 Mc and 235 Mc, respectively.

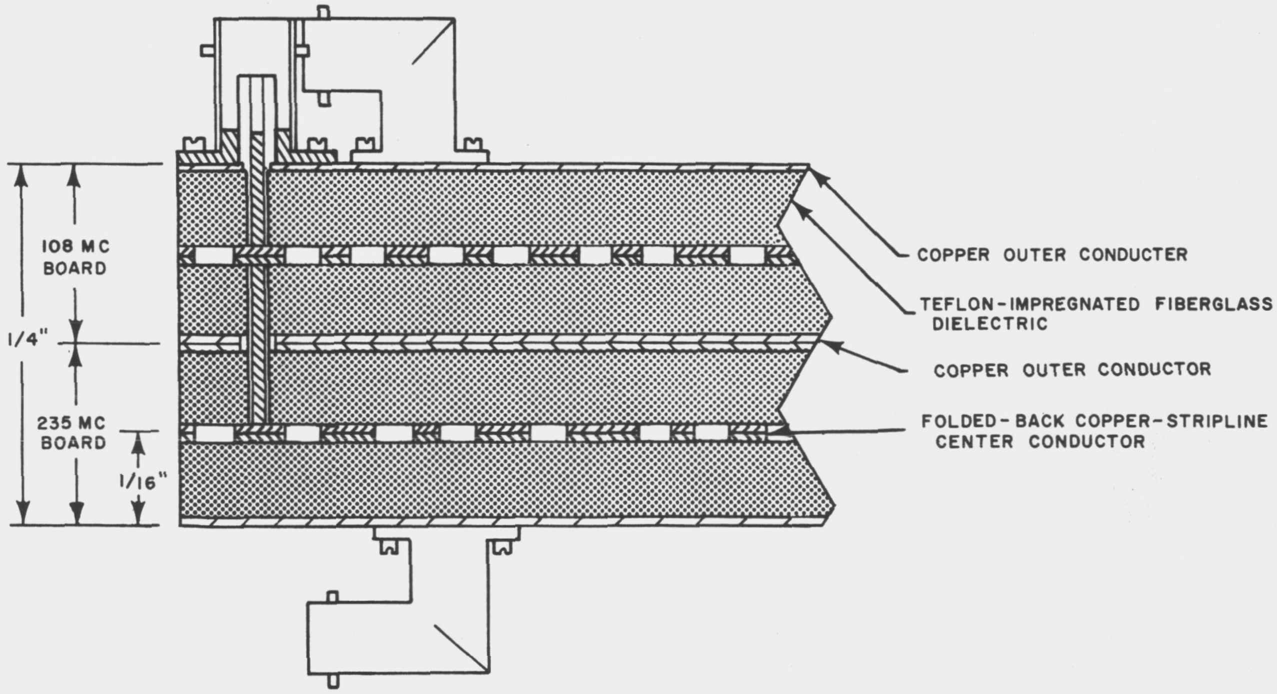


Figure 35. RF Coupling and Matching Network, Cross Sectional View

In the TIROS I system, the L1 and L2 cables could be individually tailored to optimize the impedance match at 108 Mc. By using this dual control a VSWR of 1.1, or better, was obtainable. In the TIROS II system, however, L2 was a printed line and impedance matching had to be optimized solely by adjustment of L1. But, even with this reduced control, the VSWR never exceeded 1.3.

As in TIROS I, the $\lambda/2$ (at 235 Mc) stubs of the 108-Mc baluns were tailored to optimize isolation of the beacon circuits from the 235-Mc TV and the 237.8-Mc IR signals. The achieved isolation always exceeded 35 db.

Figures 36a and 36b show one plate of the 108-Mc and 235-Mc boards, respectively. The second plate of each board is a mirror image of the first. A photograph of a 235-Mc plate is shown in Figure 36c. Figure 37 shows the integrated RF coupling and matching network.

H. DYNAMICS CONTROL

The dynamics control devices employed on the TIROS II Meteorological Satellite included: (1) the YO-YO despin mechanism; (2) the TEAM precession damping mechanism; (3) the spin-up rockets; and (4) the magnetic attitude control subsystem. The magnetic attitude control subsystem was developed to provide control over the spin-axis motion of the TIROS II satellite. The development, design, and testing of this subsystem is described elsewhere in this report.

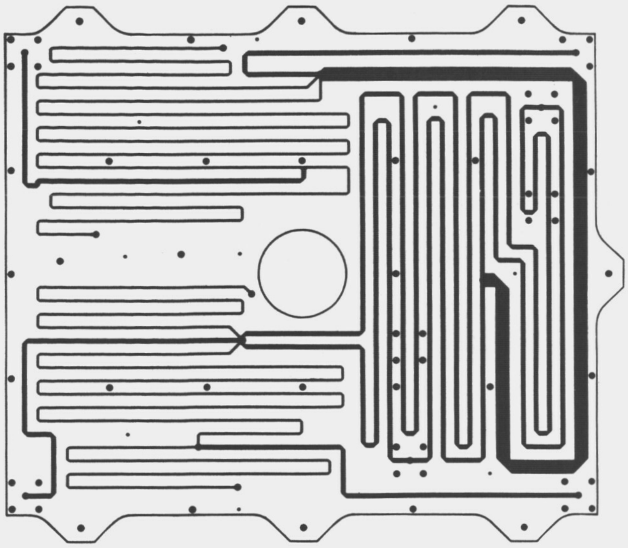
The despin and precession damping mechanisms, and the spin-up rockets were essentially the same as those used on the TIROS I satellite. The only differences were that the despin weights were increased to 47.7 grams each, and the number of spin-up rockets was increased to ten (five pairs). The need for the increase in despin weight is described in the section of this report entitled "Despin Tests." The theoretical considerations for the dynamics control equipment, excluding the magnetic attitude control subsystem, are described in Volume II of the TIROS I Final Report (Reference 1).

I. THERMAL DESIGN

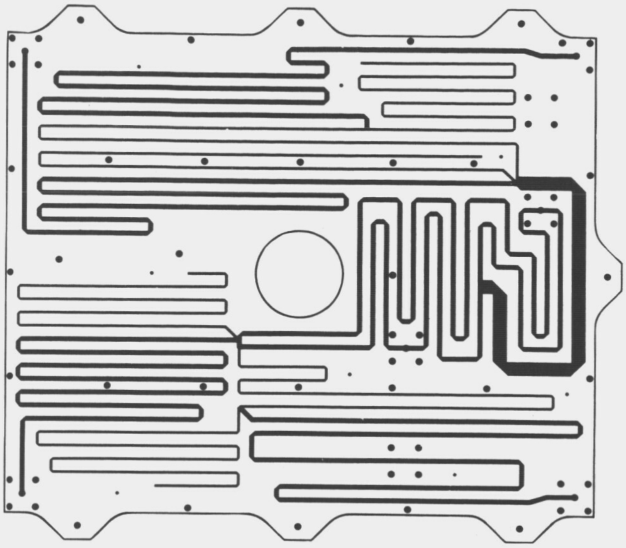
The thermal response of the TIROS I satellite was in general agreement with pre-launch computations. Therefore, the thermal analytical model of TIROS I was considered to be correct. Since the addition of the IR experiment and the attitude control circuit were not expected to have any significant effect on the satellite's thermal performance, it was assumed that the TIROS I analytical model would also be applicable to TIROS II. The thermal considerations and basic thermal equations are given in Volume III of the TIROS I Final Report (Reference 1).

Only one slight modification was made to the TIROS I thermal equations before they were used on TIROS II. This modification was made after analyses of TIROS I telemetry data indicated the presence of radiative coupling between the top and side structures of the satellite. The effect of the radiative coupling on the resulting calculated temperatures was to cause slight cooling of the top structure and slight warming of the side structure, while leaving the electronic component temperature unchanged. Since all the electronic components were grouped together in the analytical model as one thermal mass, the mass was increased slightly to account for the addition of the IR experiment and the attitude control system. However, the effect on the resulting component temperature response was negligible. Figures 38 and 39 are curves showing the forecasted TIROS II satellite temperatures for 100 percent and 68 percent sun orbits, respectively.

Determination of the temperature profile of the orbiting TIROS I satellite was complicated by three factors; namely, the limited number of temperature sensors which were employed, the location of the sensors, and the wide-range characteristics of the sensors. Accordingly, in TIROS II the number of sensors was increased



a



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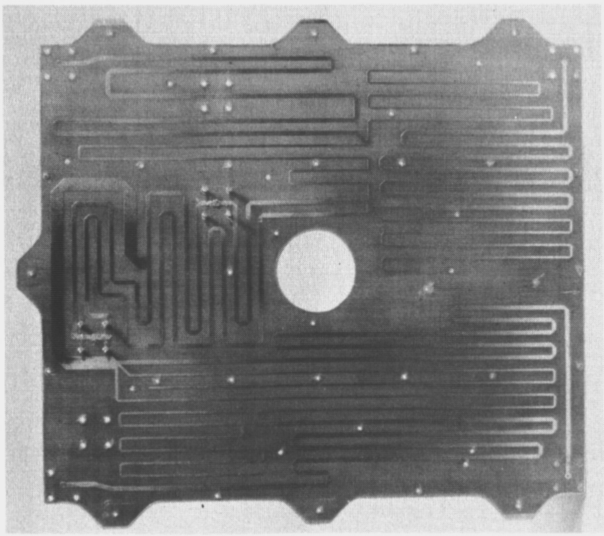


c

Figure 36. Layout of 108-Mc and 235-Mc Printed Circuit Boards

from 8 to 12, and the sensors were relocated to provide a better temperature "map" of the orbiting satellite. Also, three different types of sensors were used to provide greater "reading" accuracy. One type of sensor, a wide-range sensor identical to those used in TIROS I, was designed for linear operation between -30 and +100 degrees centigrade. The second and third types of sensors were expanded-scale, narrow-range, sensors that were designed to provide linear operation between -20 and +10 degrees centigrade, and between +10 degrees and +40 degrees centigrade, respectively.

Three temperature sensors, one wide-range and two narrow-range sensors, were affixed to the satellite's baseplate. This arrangement was designed to provide overall temperature coverage of the baseplate (-30 to +100 degrees centigrade), while also providing a higher degree of accuracy in the expected temperature range of -20 degrees to +40 degrees centigrade.

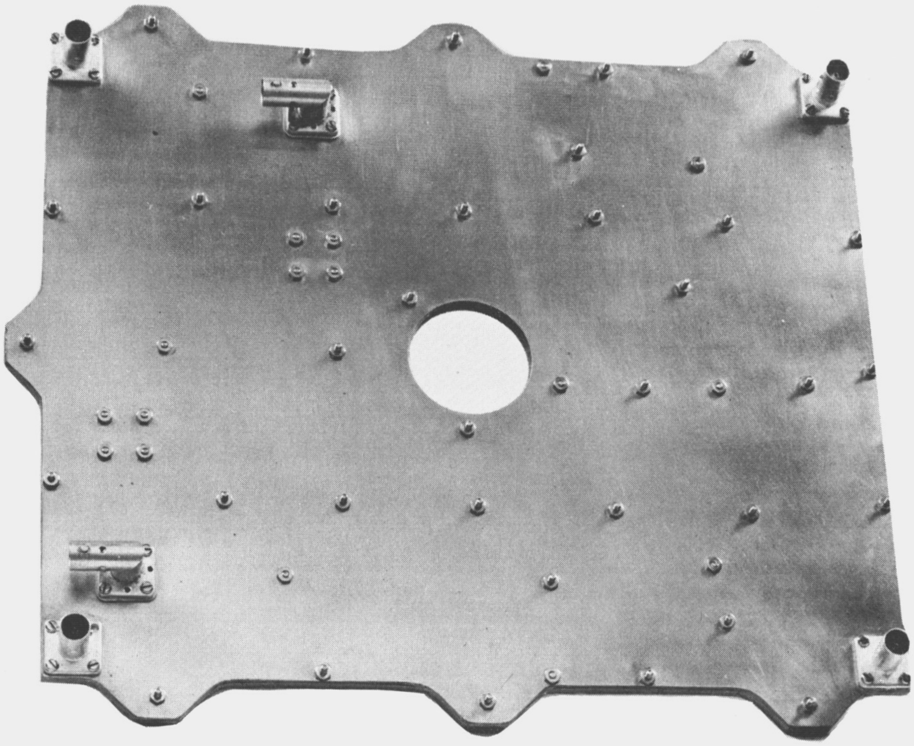


Figure 37. Integrated RF Matching and Coupling Network

Only one temperature sensor was used for checking the temperature of the satellite's side panels. The sensor, of the wide-range type, was mounted on one of the satellite's side panels. Use of only one temperature sensor was justified in that calculations based on the analytical model showed the satellite's sides to be isothermal.

Three temperature sensors were located on the top structure of the satellite. Since it was anticipated that the top would experience extreme temperature variations, the temperature sensors mounted on the top were all of the wide-range type. Two of the sensors were located on the inside surface as the top structure; one was mounted three inches from the center, the second was mounted eight inches from the center. The two sensors were

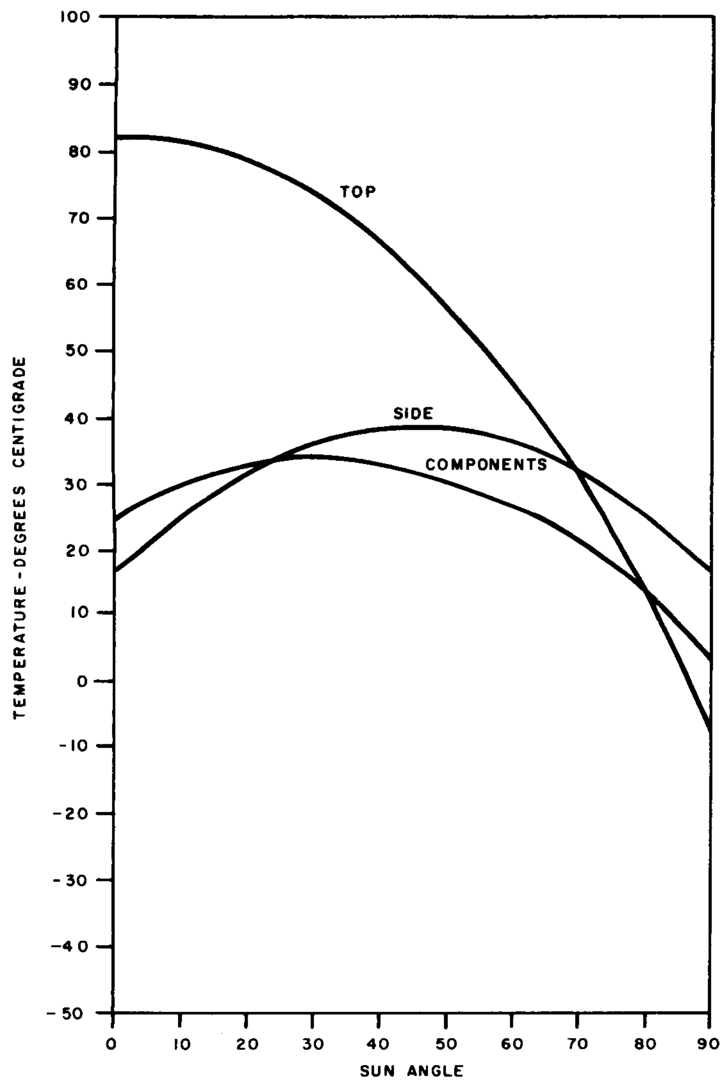


Figure 38. Forecasted TIROS II Temperature for 100 Percent Sun-Time Orbit

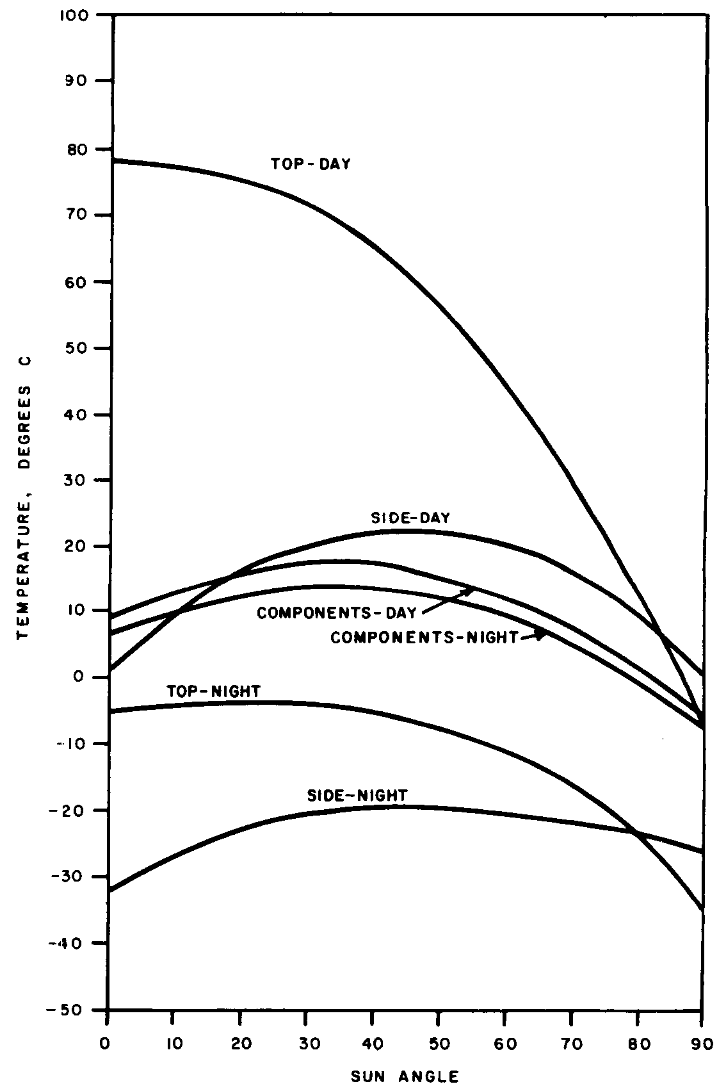


Figure 39. Forecasted TIROS II Temperature for 68 Percent Sun-Time Orbit

located in this manner to facilitate detection of temperature gradients that might be present along a radius. The third temperature sensor was mounted through a hole which was drilled through the aluminum skin of the satellite's top structure and through the epoxy glass board on which the solar cells were mounted. The hole was drilled at a point three inches from the center of the top structure. Mounting this sensor directly against the underside of a solar cell afforded a means of accurately determining the actual solar cell temperature, and also provided a means checking any gradients that might be present through the top structure.

Five temperature sensors were located on the satellite's electronic components; all of these sensors were the narrow-band type and were calibrated to operate between +10 degrees to +40 degrees centigrade. The sensors were mounted on the No. 2 TV camera, the No. 2 clock, and the battery package. The component temperatures were expected to stay generally within the +10 degrees to +40 degrees centigrade temperature range. Therefore, the temperature sensors were expected to provide accurate temperature data on the components, while eliminating confusion in differentiating between the baseplate and component temperatures. The spread between the readings of the five temperatures was expected to be small. The average of these five temperatures was expected to be the average component temperature as forecast by the analytical program.

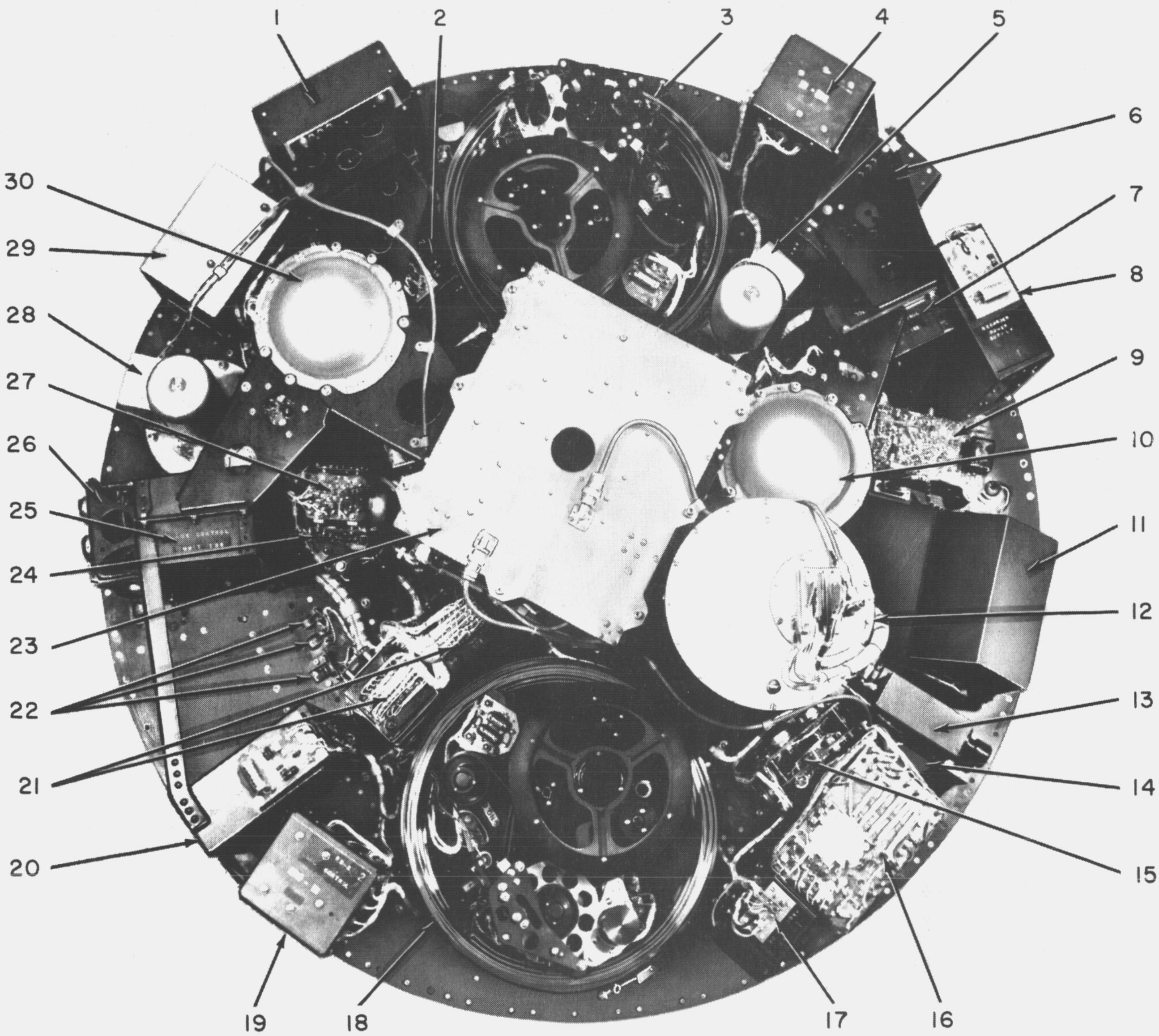
J. INTEGRATION OF SATELLITE COMPONENTS

The arrangement of the components within the TIROS II satellite was very similiar to the arrangement of components within the TIROS I satellite. The only differences were those that resulted from the improvements made on the RF matching and coupling network, and the sun sensors; and the addition of the IR experiment and the attitude control circuits. It should be noted that the IR experiment alone weighed approximately 21.5 pounds. However, weight-saving design modifications on other TIROS II components offset a portion of this additional weight so that, even with the addition of both the IR experiment and the attitude control circuit the TIROS II satellite weighed only 277.46 pounds (14.2 pounds more than TIROS I).

The RF matching and coupling network, which had been redesigned with 8.8 pound saving in weight and with nearly a 300 cubic inch saving in volume, was relocated on the top of the battery pack. The three boards of the current regulator, which were originally mounted on top of the battery rack, were also relocated. The major, or A board, of the regulator was mounted "piggy back" on top of the despin timer; the two smaller boards (B and C) were mounted on the underside of the satellite's baseplate, against intercoastal ribs.

The lift-off switches and separation-event-signal switches, which had previously been individually mounted, were mounted on a baseplate as a subassembly. In turn, the subassembly was mounted on the satellite's baseplate in such a way as to clear the tubes of the pressure system designed by Douglas Aircraft Corporation.

All nine of the north indicator's sun-sensor units were redesigned, and the cast frames in which they were mounted for TIROS I were eliminated. This resulted in 2.5-pound saving in weight. The sensing units were mounted on flat plates which were attached directly to the satellite's cover.



1. TV CAMERA ELECTRONICS PACKAGE
2. TV TRANSMITTER POWER CONVERTER
3. TAPE TRANSPORT
4. TAPE RECORDER ELECTRONICS PACKAGE
5. NARROW-ANGLE TV CAMERA
6. TAPE RECORDER POWER CONVERTER
7. TV CAMERA CONTROL PACKAGE
8. TAPE RECORDER POWER CONVERTER
9. HEAT MEASURING EQUIPMENT CONTROL PANEL AND (BELOW) COMMAND RECEIVERS
10. ELECTRONIC CLOCK
11. SCANNING RADIOMETER
12. HEAT MEASURING EXPERIMENT ELECTRONICS (AND TAPE RECORDER) PACKAGE
13. HORIZON DETECTOR
14. NON-SCANNING RADIOMETER
15. VOLTAGE REGULATORS
16. BATTERY PROTECTION PANEL AND DESPIN TIMER (BELOW) AND TV TRANSMITTER (BELOW)
17. TV TRANSMITTER POWER CONVERTER
18. TAPE RECORDER
19. TAPE RECORDER ELECTRONICS PACKAGE
20. TAPE RECORDER POWER CONVERTER
21. MAIN TELEMETRY SWITCHES
22. TEMPERATURE SENSORS
23. ANTENNA DIPLEXER AND (BELOW) BATTERIES
24. BEACON TRANSMITTERS
25. AUXILIARY CONTROL PACKAGE
26. VOLTAGE REGULATOR
27. ATTITUDE CONTROL SWITCH
28. WIDE-ANGLE TV CAMERA
29. SYNC GENERATOR AND (BELOW) TV TRANSMITTER
30. ELECTRONIC CLOCK

Figure 40. Location of TIROS II Satellite Components

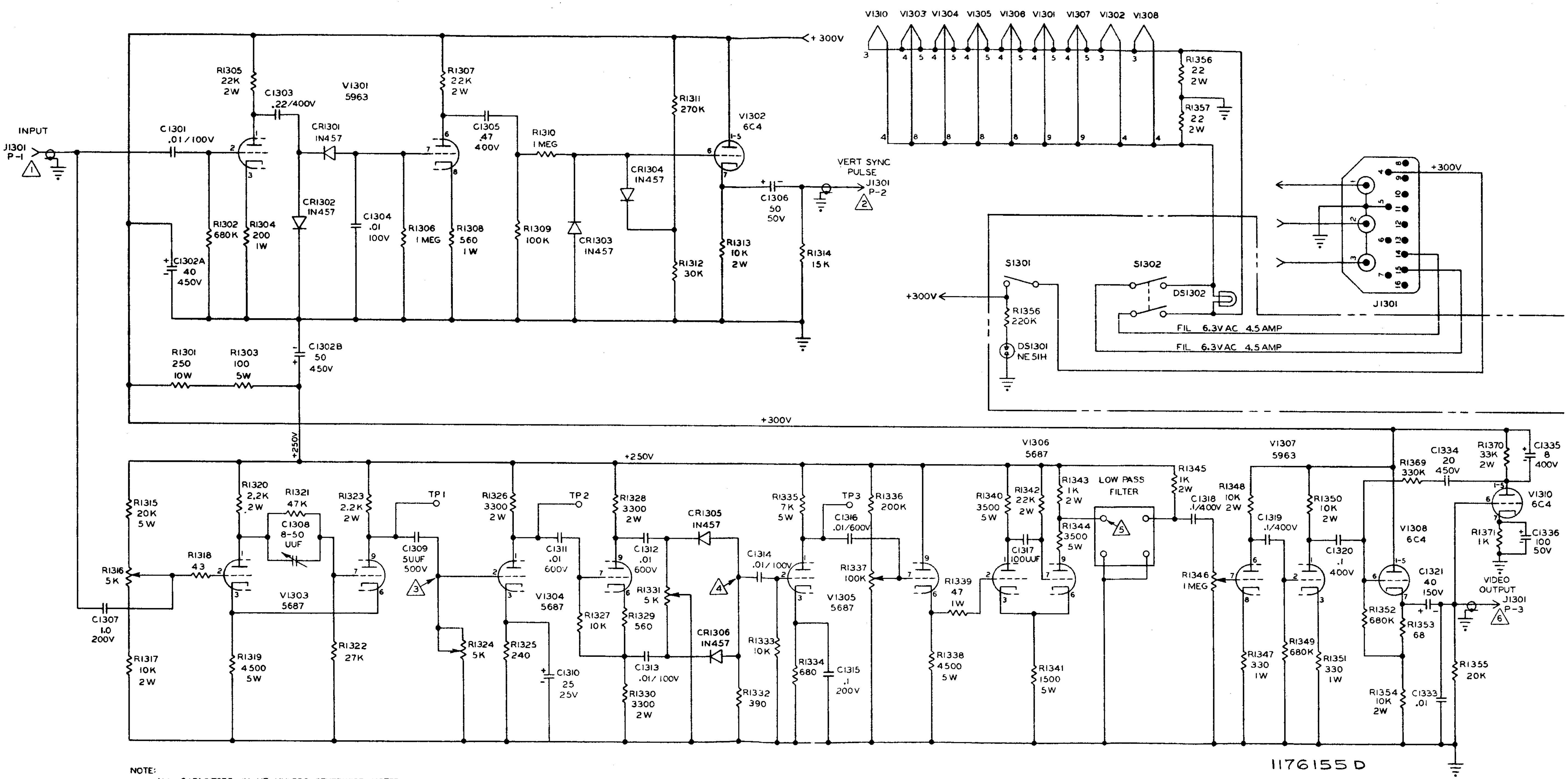
The IR package was mounted in the area that had been prepared (but not used) for this purpose during TIROS I, and was bolted directly to the baseplate. The IR non-scanning radiometer had to be mounted below the baseplate in order to accomodate a field-of-view which was larger than had originally been specified. After testing showed that the proximity of the structure caused false signals to be relayed to the non-scanning sensor, the mounting brackets were altered to increase the distance between the sensor and baseplate by 9/16 inch.

The IR scanning sensor was also mounted in a previously prepared area. However, certain revisions were necessary in order to provide electrical isolation of the sensor and the satellite's baseplate. This isolation was achieved by installing a mylar sheet under the mounting pads, and by using flanged bushings of fiber glass and epoxy in the mounting holes.

The board which housed the IR control circuit was mounted on top of the two command transmitters. The RF switch, which was added to provide the capability for transmitting IR data, was bolted directly to the satellite's baseplate, adjacent to the battery pack. Narrow- and wide-range temperature sensors, added to provide more complete data on the satellite's thermal profile, were mounted at various points on the components and the satellite structure.

Because of mounting area limitations, the attitude control device presented the major integration problem. It was finally decided that a 250-turn magnetic coil, wrapped around the periphery of the satellite's cover, would provide the most practical means of attitude control. Accordingly, shallow channel sections of fiber glass and epoxy were mounted on the side panels at a point slightly above the satellite's baseplate, and 250 turns of No. 30 lacquered aluminum were wound on these channels. The ends of the coils were attached to terminal leads, which, in turn, were connected into the attitude control circuits. In addition to the coil, two small bar magnets were attached to the satellite's understructure, parallel to the spin-axis.

Figure 40 is a cover-off view of the TIROS II satellite showing the major components and assemblies. The positioning of the attitude control coil can be seen on the Frontispiece of this report.



NOTE:
ALL CAPACITORS IN UF UNLESS OTHERWISE NOTED.
ALL RESISTORS IN OHMS .5 WATT UNLESS OTHERWISE NOTED.
FOR LIST PARTS SEE DWG NO. A-1170414.

Figure 14. Sun-Sensor Electronics, Schematic Diagram

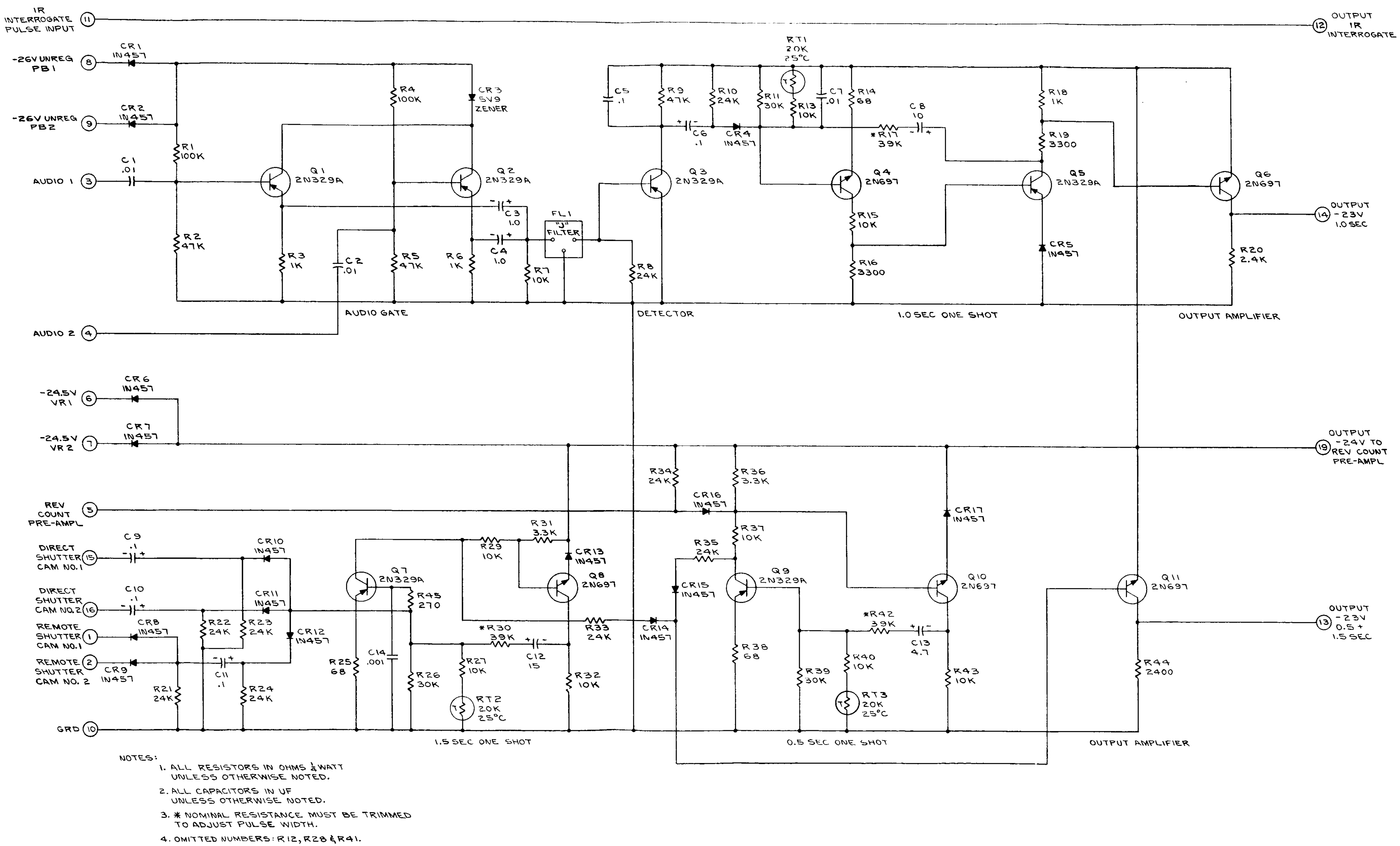


Figure 28. Infra-Red Control Unit, Schematic Diagram

SECTION III. GROUND STATION COMPONENTS

A. INTRODUCTION

Ground operations for the TIROS II Satellite System consisted, in general, of (1) tracking the satellite's position, (2) commanding the satellite's instrumentation to perform specific functions in a given order, and (3) receiving, storing, and processing data received from the satellite. These operations were performed and coordinated by a ground complex (diagrammed in Figure 41) which included* two primary Command and Data Acquisition (CDA) stations, one located in the Pacific Missile Range (PMR) and the other at Fort Monmouth, New Jersey; a secondary CDA station located at the RCA Space Center, near Princeton, New Jersey; and selected stations of the NASA Minitrack Network. In addition, a checkout (Go, No-Go) station, installed at Cape Canaveral, Florida, was included in the ground complex for performing prelaunch checkout of the TIROS II satellites.

The primary purposes of the CDA stations were as follows:

1. To transmit radio signals to the satellite for programming its operation and data transmission
2. To receive signals carrying the television, attitude, infra-red and telemetry data from the satellite
3. To extract the television, attitude, infra-red, and telemetry data from the carrier signals
4. To record the received data and to provide a means of identifying that data
5. To relay the recorded attitude and telemetry data, along with station status reports, to the NASA TIROS Technical Control Center in Washington, D.C.

The precision tracking capabilities of the selected stations of the Minitrack Network were used for accurately determining the satellite's orbital parameters.

B. SUMMARY OF MODIFICATIONS MADE FOR TIROS II

The following additions and changes were made to the TIROS I Primary CDA stations to prepare them for use in the TIROS II Satellite System:

1. The two Ampex Model FR104 tape recorders were replaced with seven-channel, Ampex Model FR100A, tape recorders.

*The ground complex included other facilities involved in the satellite command program and in data processing. However, the facilities mentioned here are those that were in direct communication with the satellite.

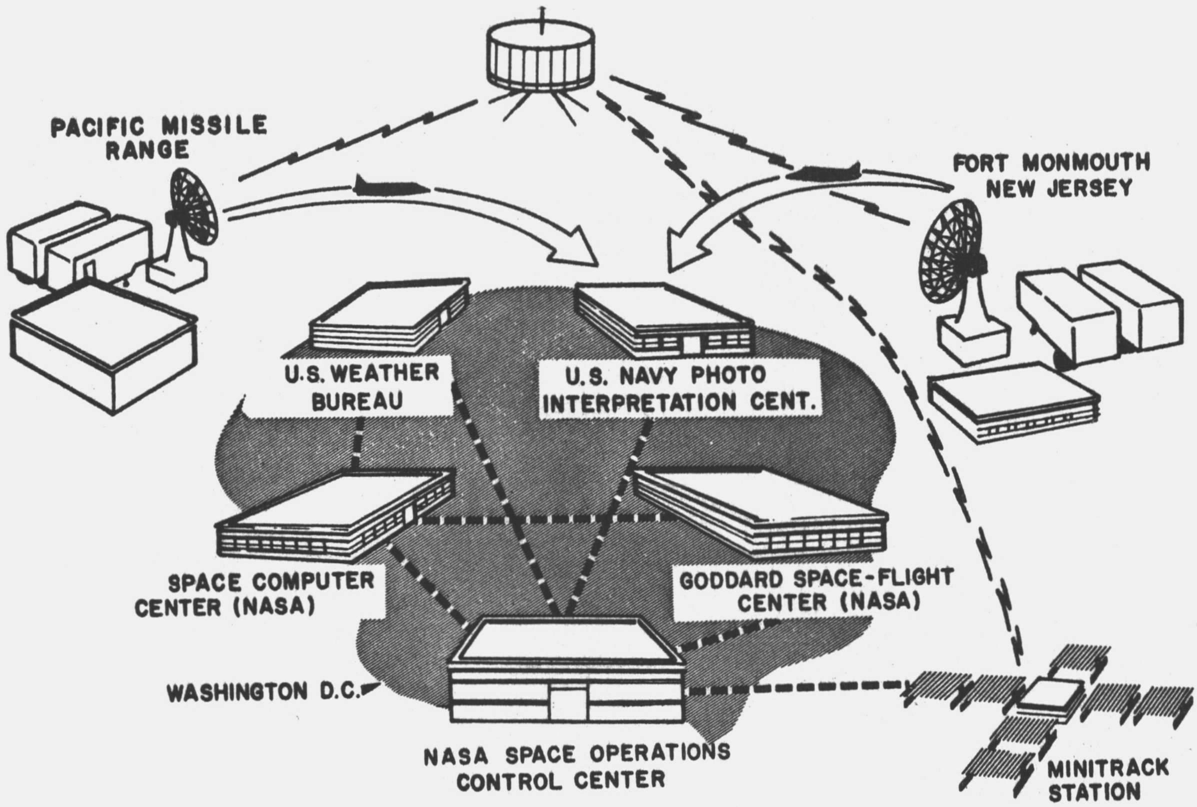


Figure 41. TIROS II Ground Complex

2. The elapsed time counter-scanner was modified and renamed the digital time measuring device (DTMD). A second DTMD was added to the system for handling the infra-red channel 4 (I-4) data.
3. An IR buffer unit was added for processing channel 5 and channel 6 IR data to make the data acceptable for application to the DTMD.
4. A government-furnished, quick-look demodulator was added for processing the non-scanning IR data.
5. The attitude pulse selector was modified so that it would accept the attitude data, in analog form, while rejecting spurious pulses.
6. Provisions were made for recording the analog attitude data on the Sanborn chart recorder.
7. A real time indicator was added to the display rack.
8. The display rack's camera mount was modified to permit Polaroid and 35-mm pictures to be taken simultaneously.
9. The master clock was modified, and a WWV comparator and a precision frequency standard were added in order to meet the timing accuracy required by the IR experiment.

10. A new command tone and new gating system were provided to produce an IR end-of-tape pulse.

11. The FM demodulator was modified to provide a greater immunity to transients.

12. Modifications were made to the sun-pulse demodulator to decrease the noise level of the inputs to the sun angle computer.

13. The sawtooth and deflection amplifier was modified so that it would (1) introduce blanking during horizontal sync pulses and (2) provide greater deflection linearity.

14. The filtering circuits of the diversity combiners were modified to provide better "tracking" of rapid signal level variations.

C. FUNCTIONAL DESCRIPTION

The components of the CDA stations are divided into five functional groups; namely, the satellite command and control equipment, the data receiving components, the data processing and display components, and the recording devices.

The command and control equipment controlled the satellite functions by means of an amplitude-modulated command transmitter. Audio control tones, each tone representing a different command function, were used for modulating the command transmitter. Three modes of operation were provided for commanding the satellite; they were: manual-operate, manual-start, and automatic. In manual-operate, which was used only during test, all satellite commands were initiated manually. During manual-start operation, only the program sequences were started manually; once the sequence started, the commands within the sequence were initiated automatically. In automatic operation, all sequences, and all commands within a sequence, were transmitted without manual intervention.

The TV picture (and sun-angle data) receiving circuit consisted of two receivers that were connected in polarization diversity to minimize signal fading due to satellite spin and attitude. The telemetry receiving circuits consisted of four receivers. Two of the receivers were tuned to the upper telemetry frequency, and two were tuned to the lower telemetry frequency. The two receivers of each pair were connected in polarization diversity. Two receivers, connected in polarization diversity combination, were also used for reception of the IR data.

Each TV picture received was displayed on a kinescope, mounted in the display unit. A panel, framing the kinescope, was equipped with a clock that provided a real time indication, and legends and numbers that were illuminated to indicate the mode (direct camera or tape playback), camera source (1 or 2), frame number, sun angle, and orbit number for each TV picture. Mode and camera source information was derived from outputs of the command and control equipment. The frame number was generated by a binary counter, which was stepped by the vertical sync pulse of each TV picture received. The frame number, consisting of six binary bits, and the mode and camera source data, consisting of three binary bits, were stored in a shift register from which a serial output and a parallel set of outputs were taken. The parallel output controlled read-out lamps which were photographed along with the kinescope display; the serial output keyed oscillators to record the camera source and frame information on magnetic tape. A parallel set of outputs comprising the binary-coded sun-angle data from the sun-angle computer were recorded on another channel of the magnetic tape. The orbit number was displayed by means of manually-set, illuminated dials. A camera, mounted on the display unit, was used to photograph each picture displayed on the kinescope and the associated identification data.

The recording devices used at the primary TIROS II ground stations were two Ampex Model FR100A, seven-channel, tape recorders and an Esterline Angus Model AW events recorder. The events recorder provided a real time recording of the initiation of the various satellite commands and of other vital ground system operations. The tape recorders recorded the TV pictures received from the satellite and the related identification information, as well as the IR data received from the satellite. Each recorder used one-half inch wide tape at a recording speed of 60 inches-per-second. During the post-pass phases of operation, the recorders were played back at 3-3/4 inches-per-second to permit certain of the IR data to be recorded on punched tape. The tape recorders were remotely controlled by the command and control equipment to start automatically at the beginning of each ground-to-satellite contact.

D. PHYSICAL CONFIGURATION

The components of the TIROS II ground stations were mounted on roll-out assemblies and housed in vertical racks which had an overall height of 65-3/8 inches. Each roll-out assembly consisted of a front panel and two vertically mounted chassis; the vertical chassis were arranged so that the tubes faced inward and the wiring faced outward. This combination of chassis mounting and roll-out slides facilitated maintenance and trouble-shooting. The vertical mounting of the chassis also provided a chimney effect which assisted materially in cooling.

The equipment racks at Fort Monmouth were mounted in the building that had housed the TIROS I equipment. The equipment at the PMR was divided between two sites; namely San Nicolas Island and Point Mugu. The equipment located on San Nicolas included all the receiving, command, IR, attitude, telemetry, and data tape recording equipment, as well as a portion of the TV subsystem. The remainder of the TV subsystem was located at Point Mugu along with the facilities required for photographic processing and meteorological interpretation of the TV film.

E. SATELLITE COMMAND AND CONTROL EQUIPMENT

1. General

The satellite command and control equipment provided a reliable means for turning on the command transmitter, programming the antenna to follow the predicted path of the satellite, turning on the TV and data recorders, initiating the transmission of control tones to the satellite, and turning off the equipment at the end of a satellite-to-ground contact.

The components of the command and control equipment were contained in three racks. Racks 1 and 3 were identical; each contained a full set of programming equipment. Rack 2 contained the timing equipment, program selector, and power control switches and relays.

Basically, the equipment was the same as that used in the TIROS I system; the primary differences included revisions to increase the accuracy of the timing circuits (necessitated by inclusion of the IR experiment), to accommodate control of the satellite's attitude control coil, and to provide IR end-of-tape pulse. The changes are described in detail in the following sub-paragraphs.

2. Functional Operation

Figures 42 and 43§ are functional and detailed block diagrams, respectively, of the TIROS II command and control equipment. Functionally, the equipment consisted of two separate programming circuits, one program selector, and one timing circuit. The timing circuit, consisting of the master clock, the WWV receiver, the WWV comparator, and the frequency standard, was common to both programming circuits. The positioning of switches and control relays on the program selector determined which programming circuit would be used for a specific satellite pass.

The ground station components of the satellite command and control equipment provided for the selection of three modes of operation: automatic, manual-start, and manual-operate. Briefly, the system operation during these operational modes was as follows:

a. Automatic. During automatic operation the program was setup in advance on the control equipment. Each program sequence started in response to an alarm signal from the master clock and proceeded to its conclusion without the aid of an operator.

b. Manual-Start. During manual-start operation, the program was also setup in advance. The only difference between manual-start and automatic was that pushbutton controls were used in place of the master clock for initiating the alarm signals.

c. Manual-Operate. During manual-operate, a pre-setup program was not used. Instead, the program sequences were initiated by means of pushbuttons which were also used to carry each sequence through to completion.

The two separate programming circuits permitted two complete programs to be setup in advance. These programs could be setup for consecutive orbits or could be setup to provide alternate programs for the same orbit. The program sequences used in TIROS II and the alarms which controlled these sequences are as follows:

a. Direct Camera Sequence I. Direct camera sequence I was controlled by alarm number 1. This program sequence was used when the TV pictures were to be taken while the satellite was in range of a ground station. When the satellite was in the direct camera sequence, the pictures were transmitted directly to ground, bypassing the satellite's tape recorders. Either one of the satellite's TV cameras could be commanded to take pictures at either a

§ This illustration is printed on a foldout page located at the rear of this Section.

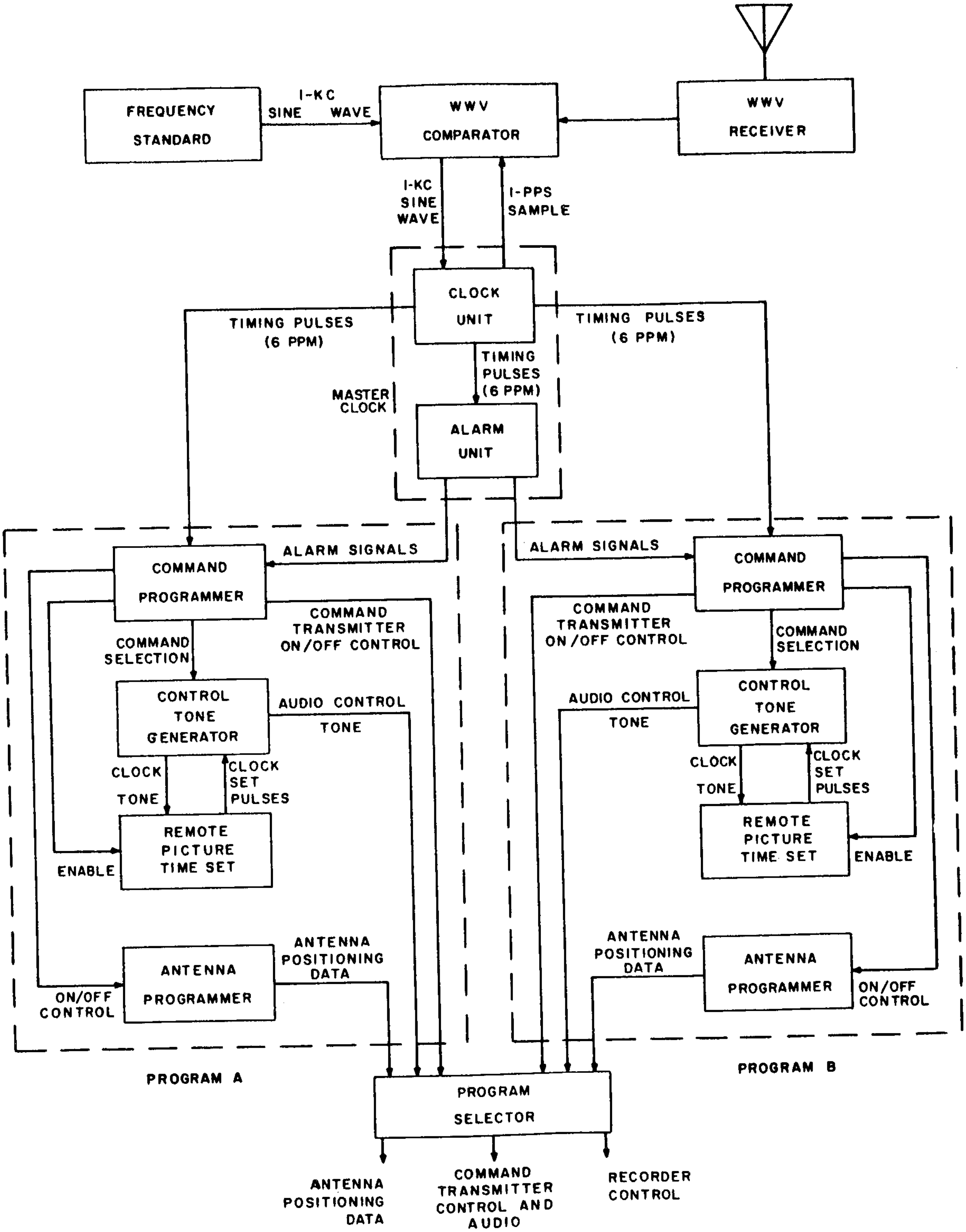


Figure 42. Command and Control Equipment, Functional Block Diagram

10-second or a 30-second interval. Picture taking commands could be alternated from one camera to the other at an interval of 30 seconds. The length of the sequence could be varied between 0.5 minute and 8.0 minutes in 0.5 minute increments.

b. Playback and Clock-Set Sequence. The playback and clock-set sequence, initiated by alarm 2, included (a) commanding the satellite to read-out pictures which had been recorded on the satellite's tape recorders since the last ground-to-satellite contact, and (b) shortly after the start of playback, sending an IR end-of-tape pulse. Also during this sequence, set pulses could be sent to the vehicle clocks and, at the conclusion of the set pulses, a start pulse (alarm number 3) could be sent to the clocks.

c. Direct Camera Sequence II. Whenever this sequence was programmed, it followed directly after the playback sequence. In addition to providing for the same program variations as direct camera sequence I, this sequence provided for the automatic transmission of a predetermined number of attitude control pulses.

In addition to the functions listed for each sequence, any of the program sequences could include the sending of manually initiated "fire spin-up rockets" commands, as well as manually initiated commands for stepping and reading-out the position of the attitude control switch.

3. Timing Circuits

a. General

The timing circuits, consisting of the master clock, WWV receiver, WWV comparator, and frequency standard, generated the alarm signals that initiated the various sequences of a program during automatic operation. Although the timing circuits developed for TIROS I performed within their design specifications and met the timing requirements of that system, the addition of the IR experiment in TIROS II resulted in the requirement for a timing pulse whose real time could be determined to within four milliseconds. Because of this more stringent requirement, the clock unit of the TIROS I master clock was replaced with a unit that provided digital readout, the WWV comparator was added to the timing circuits, and a precision frequency standard was procured.

The new clock unit, developed by General Time Corporation, was designed for use with the alarm unit of the master clock used in the TIROS I system. The clock unit employed the same type of Burrough's decimal counters as were used in the remote picture time set unit.

The Lavorie LA-90 frequency standard, selected for use in the TIROS II timing circuits, provided a frequency stability of one part in 10^9 per 24 hour period. This stability was attained by the use of a plano-convex crystal, operating in its fifth overtone mode, which was mounted in a crystal oven whose temperature was precisely controlled.

The WWV comparator selected for use was a Hermes Model 222. The comparator permitted the timing system to be synchronized with WWV by means of a Beckman 905R WWV receiver and oscilloscope.

The WWV comparator, WWV receiver, and frequency standard are described in their respective operating and instruction handbooks.

b. Functional Description

The 1-kc output of the frequency standard (Figure 43) is applied through the phase-shift resolver in the WWV comparator to the clock-unit of the master clock. The 1-kc signal is squared by the pulse-former and then frequency divided by three cascade-connected counters. The resultant 1-pps signal is applied: (1) to the "seconds" counter-indicator; (2) through a pulse former to the attitude recorder; and (3) through a second pulse former to the 1.0-second comparator in the WWV comparator.

The phase-shift resolver, controlled by a front panel dial, is used to correct the setting of the master clock by imparting a phase-shift to the 1-kc signal and thus momentarily slowing-down or speeding-up the cascaded counters. The 1.0-second comparator permits detection of timing errors of less than 1 second by allowing the 1-pps signals to be compared in time with the WWV ticks.

The "seconds," "minutes," and "hours" counter-indicators employ Nixie readout to provide an instantaneous display of real time. The reset circuit resets the "hours" counter-indicator to 00 at the end of each 24 hour period.

In addition to the output which advances the divide-by-six counter, the initial stage of the "seconds" counter-indicator provides two other outputs; namely, the count 8-9 output and the count 5 output. All three outputs have a 6-ppm repetition rate.

The count 8-9 output, a 2-second pulse that terminates when the counter returns to its tenth or zero position, is applied to the relay driver and then to the alarm unit. The count 5 output, a 1-second pulse that occurs 5-seconds after the corresponding count 8-9 pulse terminates, is applied to the IR time mark gate. The gate is inhibited until the start of playback; at that time, the gate allows one count 5 pulse to pass to the control tone generator and thus initiate the IR end-of-tape pulse. The nature of the alarm unit and command programmer is such that the playback sequence starts upon termination of a specific count 8-9 pulse. Therefore, the IR end-of-tape pulse is always initiated exactly 5-seconds after the start of the playback sequence.

The alarm unit contains six independent alarm circuits. Three of the circuits (1A, 2A, 3A) control the starting of the sequences of Program A; the other three circuits (1B, 2B, 3B) control the starting of the Program B sequences. Each alarm circuit contains four alarm-time dials, used for manually setting the desired alarm time in hours, minutes, and tens-of-seconds, and four associated stepping switches. The count 8-9 output, from the clock section of the master clock, cocks the tens-of-seconds stepping switches during its period and causes them to advance upon its termination. Carry-over action from the tens-of-seconds stepping switches causes subsequent stepping of the higher order switches. When the stepping switches of a particular alarm circuit have advanced to the "time" set on the alarm-time dials, the circuit sends its alarm signal to the associated programmer.

The alarms and the sequences they initiate are discussed in the functional description of the satellite command and control equipment. The schematic diagram of the master clock and master clock alarm unit are shown in Figures 44§ and 45§ respectively.

4. Control-Tone Generator

The discussion of the control tone generator involves classified information and is included, therefore, in the classified supplement to this Report.

5. Remote Picture Time Set

The discussion of the remote picture time set involves classified information and is included, therefore, in the classified supplement to this Report.

6. Antenna Programmer

The antenna programmer employed linear interpolation of ephemeris data to aim the tracking antenna at the point where the satellite was expected to come over the horizon, and also, in some instances, to cause the antenna to track the predicted path of the satellite. Use of the antenna programmer ensured faster antenna lock-on by eliminating the need for horizon scanning at the beginning of each pass. In turn, faster lock-on prevented loss of data in cases where the satellite-to-ground contact was prematurely interrupted.

The antenna programmers used in TIROS II were identical to those that had been developed for TIROS I. The development, design, and operation of the unit are described in Volume II of the TIROS I Final Report (Reference 1).

7. Program Selector and Power Control Unit

The program selector and power control unit provided selection of either Program A or Program B for transmission to the satellite. In addition, the unit provided for control of filament and plate voltages to the two programmer circuits. The development, design, and operation of this unit are described in Volume II of the TIROS I Final Report (Reference 1).

8. Relay Power Supply

The relay power supply generated the 24 volts required for energizing the relays in the ground station command and control equipment and provided for distribution of 115-volt, 60-cps, a-c to these same components. The power supply is fused to provide protection for the load circuits. Design and development of the relay power supply was based on the

§ This illustration is printed on a foldout page located at the rear of this Section.

use of standard circuits. The operation of the relay power supply is described in Volume II of the TIROS I Final Report (Reference 1).

9. Command Transmitter and Remote Control Panel

The command transmitters, residual from TIROS I, were Collins Model 242F-2, 200-watt, amplitude-modulated, VHF transmitters. Two of these transmitters were located at each ground station; only one of the two transmitters could be used at any given time. The transmitters were operated remotely because it was required that they be located within 100 feet of the transmitting antenna to avoid excessive power loss in the RF cabling.

Switching of the antenna from one transmitter to the other was accomplished by the use of a remotely operated coaxial switch. A low-pass filter, installed at the output of the coaxial switch, reduced spurious radiation above the command frequency. The 4X-150B RF output amplifier tubes normally supplied with the transmitter were replaced with 4X-250B output tubes to ensure ample reserve power output and long tube life at an output power of 200 watts.

Each command transmitter was equipped with an RF detector that was used for alignment purposes. The output of the detector, d-c current, was indicative of the transmitter power output. The detector output also contained the detected command tones which were amplified and drove a loudspeaker in the transmitter control panel. The loudspeaker output permitted audio monitoring of the outgoing command tones.

The characteristics of these transmitters are listed in the "Handbook of Maintenance Instructions for Collins 242F-2 Transmitter" (Reference 3).

The transmitter control panel was identical to the unit developed for TIROS I. It provided the following:

a. Meter indications of percent RF power output from transmitter

b. Audible indications that the transmitter was being modulated

c. Manual selection of transmitter A or B

d. Manual selection of channel 1 or 2 (redundant transmitter crystals)

e. Transmitter primary power "on-off" switch

f. Test button for test operation of transmitter

10. Command Programmer

a. General

The TIROS II command programmer, a modified TIROS I command programmer, provided the means for setting-up and storing the desired satellite program. When an alarm signal was received, the command programmer supplied related portions of this stored information to the control tone generator, antenna programmer, remote picture time set, tape recorders, and command transmitter. Two command programmers were installed at each CDA station.

The basic design of the command programmer was established during the TIROS I project. This design permitted presetting of program sequences and provided for automatic read-out of these sequences at preselected, electrically-computed times. The design of the programmer reduced the possibility of human error by affording the opportunity to check the preset programs and by minimizing the need for operator control during a satellite-to-ground contact.

Other design features included provisions for manually controlling the entire program, and for manually starting each of the program sequences. These features were not intended to be used under normal conditions; they were included to provide for control of the satellite before its path was accurately known and to provide a means of checking out the ground station equipment.

Modifications made to the TIROS I command programmer to make it compatible with the TIROS II system included the addition of an IR enable circuit, the addition of a circuit for controlling the number of attitude control pulses sent to the satellite, and a modification to the fire-spin-up-rockets control circuit.

b. Functional Description

The block diagram of the command programmer is shown in Figure 43, the detailed block diagram of the command and control equipment. The programmer has three separate channels; one channel for controlling direct camera sequence I, a second channel for controlling the playback sequence, and a third channel for controlling direct camera sequence II. The time to be allotted for each direct camera sequence is set-up by use of front panel selector switches. In addition, the time interval between picture taking commands is controlled by front panel selector switches. Another control permits selection of the camera to which the commands are to be sent. The programmer contains delay and control circuits to ensure that the satellite systems are warmed up before commands are sent to them.

A program sequence can be initiated either automatically by alarm signals from the master clock or manually by use of front panel switches. Timing of the command programmer functions, normally controlled by 6-pulse-per-minute (ppm) timing inputs from the master clock, can also be controlled either manually or by use of an internal 6-ppm clock generator.

The 6-ppm inputs from the master clock are applied to the start-relays in each of the three channels. When alarm 1 is received, the start-relay in the direct camera sequence I picks up and routes the 6-ppm inputs to the stepping switch of that channel. A d-c voltage, applied through the hold relay and closed contacts of the start-relay, causes that relay to lock-up. Each pulse advances the stepping switch one step. When the switch steps to the position corresponding to the setting of the front-panel time selector switch, the hold-relay opens momentarily and de-energizes the start-relay. This removes the 6-ppm inputs from the switch and thus stops the stepping action. Normally, the time selector switch is set to a time interval which does not allow the stepping switch to reach the time set in before the playback sequence begins. When the playback sequence begins, the direct-camera-start relay is de-energized by a momentary opening of its hold circuit stopping direct camera sequence I. By stopping direct camera sequence I in response to the initiation of the playback sequence, the possibility of overlaps and gaps in the transmission of program data is eliminated.

During the time interval between the pick-up and drop-out of the start relay, an energizing voltage is applied through the picture interval selector and the camera selector to the associated oscillator, direct 1, or direct 2, of the control tone generator and to the recording system. Also during this interval, a control voltage, sent to the program hold circuit, turns on and holds on the command transmitter, and an enabling signal is sent to the antenna programmer.

The satellite TV cameras are commanded to take a picture by interrupting the control voltage applied to the control tone generator. Interruption of the control voltage is accomplished by the picture interval selector. The selector provides two interruption rates: one rate provides for pictures to be taken at 10-second intervals; the other rate provides for pictures to be taken at 30-second intervals. When the selector is set to the 10-second position, it is connected to every tap of the stepping switch; when set to the 30-second position, the selector is connected to every third tap of the stepping switch.

The alarm 2 input starts the playback sequence and stops direct camera sequence I. Operation of the playback sequence circuit is similar to operation of the direct camera circuit except that, since cameras are not being programmed, there is no picture interval selector. A second difference is that instead of providing control over the duration of the sequence, a program selector is included to control the sequence of tape playback.

When the playback start relay energizes, a control voltage is applied through the playback stepping switch to the IR enable circuit. In response to this input, the enable circuit enables the IR time-mark gate of the master clock, allowing an IR end-of-tape pulse to be sent to the satellite. Ten seconds after the start of playback, the 6-ppm stepping input causes the playback stepping switch to advance and break the enabling circuit. This action ensures that only one IR end-of-tape pulse is sent to the satellite.

Setting of the satellite clocks is also accomplished during the playback sequence. Clock set is initiated 10 seconds after the satellite has been set to the playback mode. The clock-set time occurs at either one of two fixed intervals after alarm 2, depending on the programmed sequence. The start-clock command is initiated by alarm 3. Outputs of the "set clock" circuits consist of enabling and "set" signals which are applied to the remote picture time set, and a "start" signal which activates the clock set oscillator in the control tone generator.

Direct camera sequence II, when called for, is started at the conclusion of the playback sequence by an output from the program selector. Operation of the sequence II circuit is similar to the operation of the direct camera sequence I circuit. The only difference is that the sequence II circuit has provisions for initiating the automatic transmission of attitude control pulses to the satellite. Automatic transmission of these pulses, when programmed, commences two minutes and twenty seconds after the start of direct camera sequence II. The number of pulses to be sent is determined by the setting of the attitude control selector switch.

In addition to the functions listed, any one of the three program sequences can also include the manually initiated position-monitoring of the satellite-borne attitude control switch, the manually initiated transmission of the fire-spin-up-rockets command, and the manually initiated transmission of single attitude control pulses. Monitoring of the position of the satellite-borne attitude switch is achieved by setting the ground-station attitude control switch to one of its attitude positons and then holding the attitude control pushbutton depressed for slightly less than six seconds. (Holding the pushbutton depressed for longer than six seconds causes the satellite's attitude switch to advance one position.)

Transmission of the fire-spin-up-rockets command is achieved by setting the attitude control selector switch to the spin-up position and depressing the spin-up fire pushbutton.

The schematic diagram of the command programmer is shown in Figure 46§

11. Clock Set-Pulse Demodulator

The clock set-pulse demodulator, used in conjunction with the back-up Berkeley counters, provided an accurate count of the "set" pulses sent to the satellite clocks. This unit received its input from the RF detector circuit of the command transmitter. Circuits within the demodulator separated the detected "clock-set" pulses from the remainder of the detected command tones and then applied these pulses to the Berkeley counter located in Rack 12. The development, design, and operation of the clock set-pulse demodulator are described in Volume II of the TIROS I Final Report (Reference 1).

F. DATA RECEIVING COMPONENTS

1. Introduction

The data receiving components consisted of the TV receivers, the IR receivers, the beacon and telemetry receivers, and the TV and IR diversity combiners. Except for the diversity combiners, the equipments selected for use as data receiving components were in either military or commercial use at the start of the TIROS contracts. The diversity combiners used in the TIROS II system were improved models of the TIROS I combiners; they provided polarization diversity connection for the horizontal and vertical TV and IR receivers. Polarization diversity combination for the beacon and telemetry receivers was accomplished by interconnecting the AGC's of the vertical and horizontal receivers for each of the beacon frequencies.

2. TV and IR Receiving Circuits

The TV and IR receiving circuits consisted of two TV receivers, tuned to 235 Mc, two IR receivers, tuned to 237.8 Mc, two bandpass filters, and two diversity combiners. Figure 47 is a block diagram of the TV and IR receiving circuits.

§ This illustration is printed on a foldout page located at the rear of this Section.

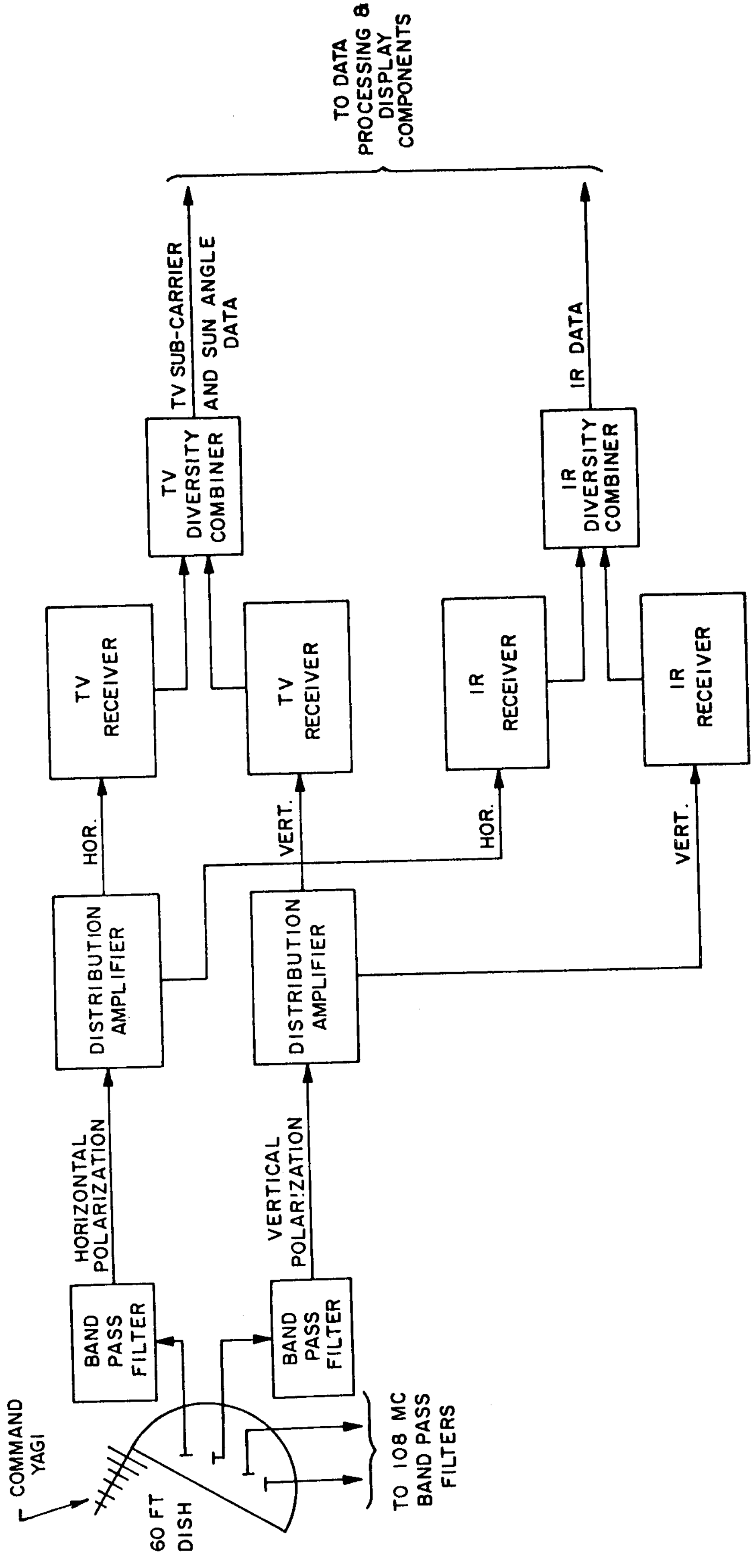


Figure 47. TV and IR Receiving Circuits, Block Diagram

The horizontally and vertically polarized outputs of the tracking antenna are applied through bandpass filters before being applied to their respective TV and IR receivers. The filters, used to prevent interference from the command transmitter, were residual from TIROS I. In order that they could be used to pass both the IR and the TV signals, the filters were peaked at 236.5 Mc. (Figure 48 shows a typical frequency response pattern.)

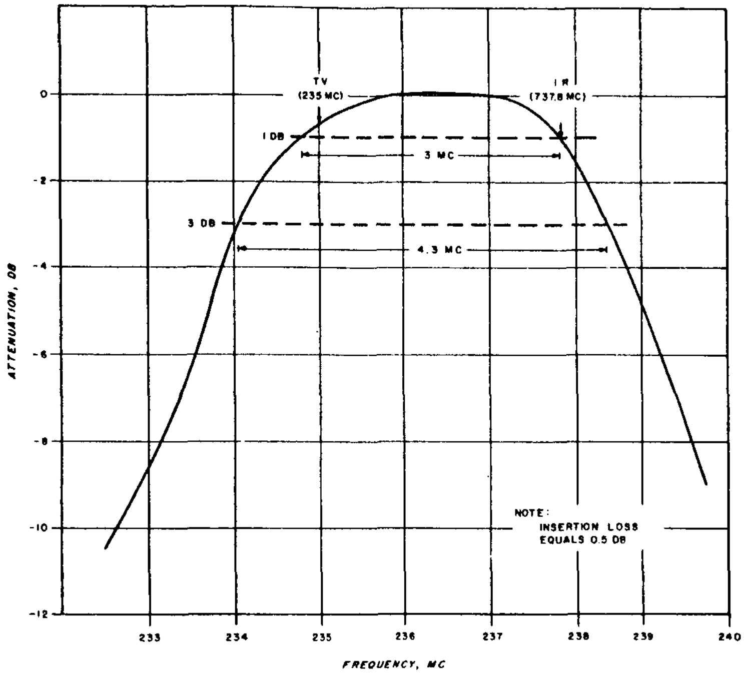


Figure 48. Frequency Response of TV and IR Bandpass Filters

The TV and the IR receivers, also residual from TIROS I, were either Nems-Clarke Model 1411 or Nems-Clarke Model 1412. Although the Model 1412 receivers were considered superior, they were not available in sufficient quantity on the procurement date; therefore, most of the receivers were Model 1411.

The signal output and AGC voltage of the IR horizontal receiver and vertical receiver were applied to the same diversity combiner. Similarly, the outputs of the two TV receivers were applied to a second diversity combiner. Each diversity combiner selected the stronger of its two signal inputs for application to the succeeding stages of the TV or IR receiving circuits.

3. Beacon and Telemetry Receivers

The beacon and telemetry receiving circuits consisted of four R-390A receivers, two Tape-Tone frequency (108 to 14 Mc) converters, two multicouplers, and two F192/U, 108-Mc bandpass filters. All of this equipment was residual from TIROS I.

Two of the R-390A transmitters were tuned to 14.00 Mc; the other two were tuned to 14.03 Mc. One receiver of each frequency group was connected to a multicoupler which, in turn, was connected to the horizontally polarized feed from the antenna system; the other receiver and multicoupler of each group were connected to the vertically-polarized feed from the antenna system. The two receivers of each frequency group were connected together in polarization diversity combination.

The Tape-Tone converters, modified by the addition of crystal ovens, provided a frequency stability of ± 0.001 percent. At PMR, since the Tape-Tone converters had to be rack-mounted in vans, the telemetry signals were preamplified before leaving the antenna. At Fort Monmouth, the Tape-Tone converters were mounted in the antenna pod as an integral unit which also contained the 108-Mc bandpass filters. The filters provided 40 db of attenuation to the command transmitter frequency while resulting in an insertion loss of only 1 db. The F192/U bandpass filters were used in this application instead of notch filters because of the availability of the F192/U as government-furnished equipment.

4. Diversity Combiner

a. General

Three diversity combiners (one for TV, one for IR, and one spare) were employed in the TIROS II System. The diversity combiners were very similar to those used in TIROS I; the primary difference was that the TIROS II combiners employed four-stage, instead of single-stage, filtering networks. This change was made after it was noted that the single-stage filters used in the TIROS I combiners could not follow rapid variations in signal level and that this inability had often resulted in noise bursts (approximately 0.5 second in duration), which obscured picture detail. The new four-stage filters had time constants of only 40 milliseconds. This reduced time constant permitted the combiner to track each signal fade and thus lessened the possibility of noise bursts.

A second change was made to the combiners to permit the receiver AGC voltages to be recorded on the Ampex tape recorders. This change involved feeding the receiver AGC voltages through a 200K resistor to the 10K input resistor of each tape recorder. Use of this feed through technique permitted the recording of the AGC voltages while preventing the loading of the AGC circuits.

b. Functional Description

The block diagram of the diversity combiner is shown in Figure 49. The combiner receives the video signal and corresponding AGC signal from each of its two associated (IR or TV) receivers. The video signals are applied through an attenuator directly to the grids of the cathode-coupled combining tube. The signal on the combiner grids is limited

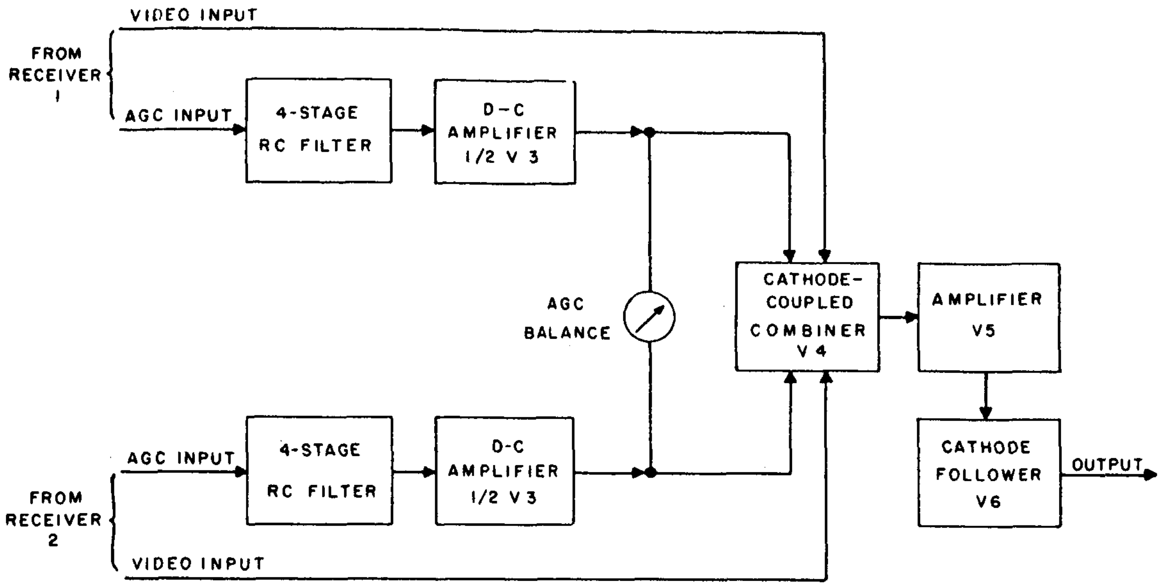


Figure 49. Diversity Combiner, Block Diagram

to 0.1 volt peak-to-peak to ensure minimum distortion and to reduce cross-modulation between the video subcarrier and the sun pulses. The AGC voltage inputs are applied through 4-stage, low time constant, RC filters to d-c amplifier V3. After amplification, the voltages are applied to the grids of combiner V4.

The combiner senses the level of the AGC voltages to determine whether one or both of the video signals should be applied to amplifier V5. In cases where the two video signals are within 2 db of one another, the AGC voltages are such that tube V4 will allow both video signals to be applied to amplifier V5. If the signals are not within 2 db, the corresponding difference in AGC levels results in the lower amplitude video being blocked by V4. Amplifier V5 ensures unity again through the diversity combiner.

The AGC balance control is included to permit balancing of the two outputs of V3 when the inputs to the receivers are equal. Figure 50 is the schematic diagram of the diversity combiner.

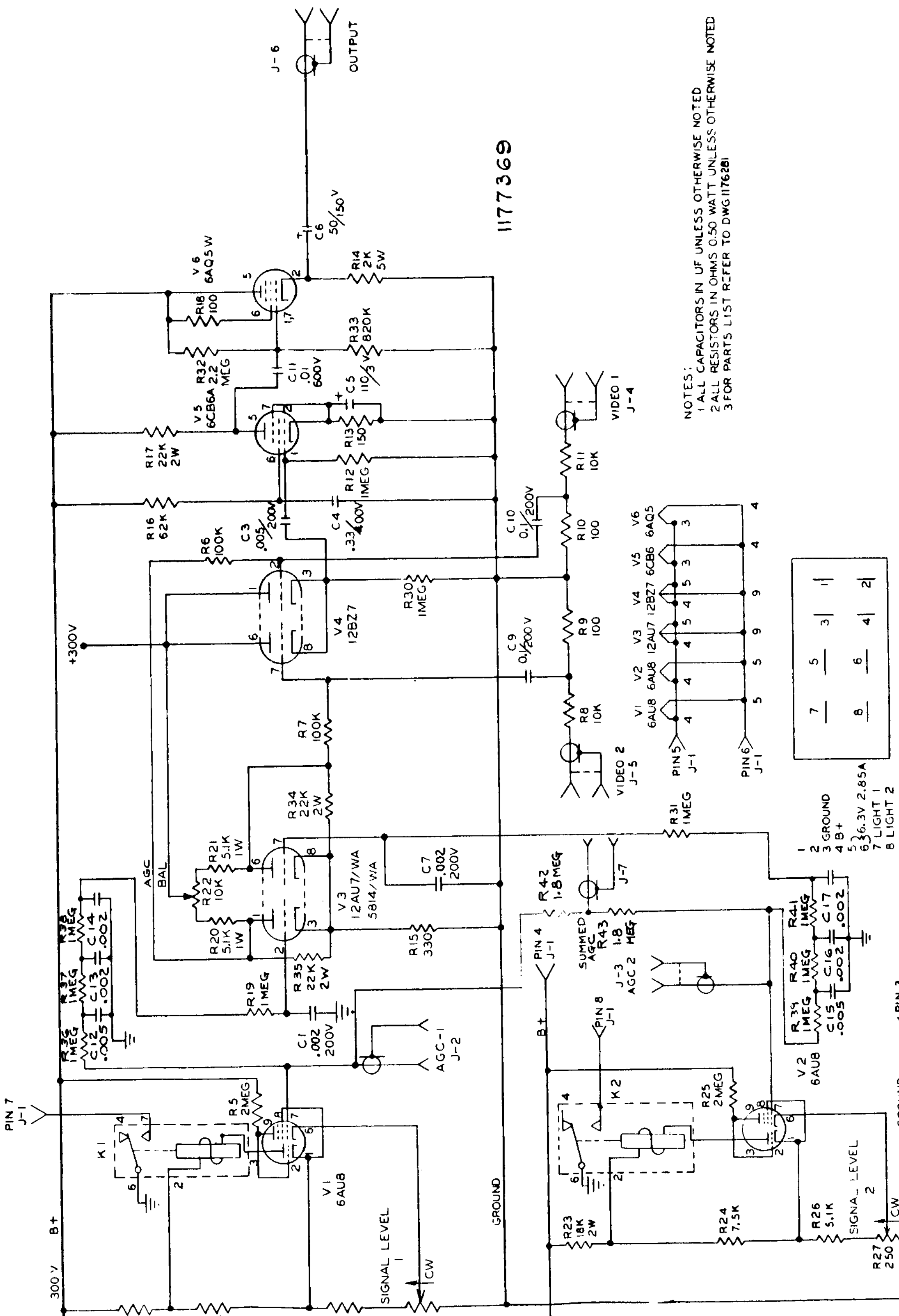


Figure 50. Diversity Combiner, Schematic Diagram

G. DATA PROCESSING AND DISPLAY COMPONENTS

1. General

The data processing and display components received and demodulated the TV transmission from the satellite, and recorded the resultant TV pictures on film and magnetic tape. These components also provided identification and orientation information (frame number, orbit number, satellite camera identification, picture taking sequence, real time, and sun angle) for each picture. A playback system, included to facilitate meteorological interpretation of the pictures received from the satellite, permitted the generation of duplicate positives and negatives.

The TIROS II data processing and display components were similar to those used in TIROS I. The primary differences included the addition of a real time indicator, and modifications to: (1) the sawtooth and deflection amplifier to decrease 60-cycle hum and to provide blanking signals; (2) the TV-FM demodulator to improve its transient response; (3) the tape and computer control to improve its handling of inputs having low signal-to-noise ratios, and (4) the camera mount to allow 35-mm and polaroid pictures to be taken simultaneously.

2. Functional Description

Figure 51 is the block diagram of the data processing and display components. The input signal is a composite of the frequency multiplexed TV subcarrier and the sun-pulse signals from the TV diversity combiner. The sun pulses are separated from the subcarrier by means of a high pass and a low pass filter. The sun pulses are applied through the 10-kc low pass filter to the tape recorder, and to the tape and computer control where the 10-kc pulses are filtered and detected. The detected envelopes of these pulses are applied to the sun angle computer. The TV subcarrier is applied through the 18-kc high pass filter to the tape recorder and to the TV-FM demodulator. In addition to demodulating the TV subcarrier, the demodulator circuit serves as a vertical sync separator. The video output of the TV-FM demodulator is applied to the horizontal sync separator, a monitor scope, and the video amplifier of the display and video amplifier unit.

The output of the horizontal sync separator and the vertical sync output of the TV-FM demodulator are applied to the sawtooth and deflection unit. In turn, the sawtooth and deflection unit provides the vertical and horizontal deflection currents, and the blanking pulses for the kinescope.

3. Display and Video Amplifier

The display and video amplifier provided final amplification of the TV video and presented the associated TV picture on a display panel. The display panel included indicator lamps that were illuminated by inputs from the other data processing and display components to provide picture identification data. In order to provide a photographic recording of each TV picture and its related identification information, a camera mount was included as part of the display and video amplifier. The camera mount, government-furnished equipment from TIROS I, was modified so that 35-mm and polaroid pictures could be taken

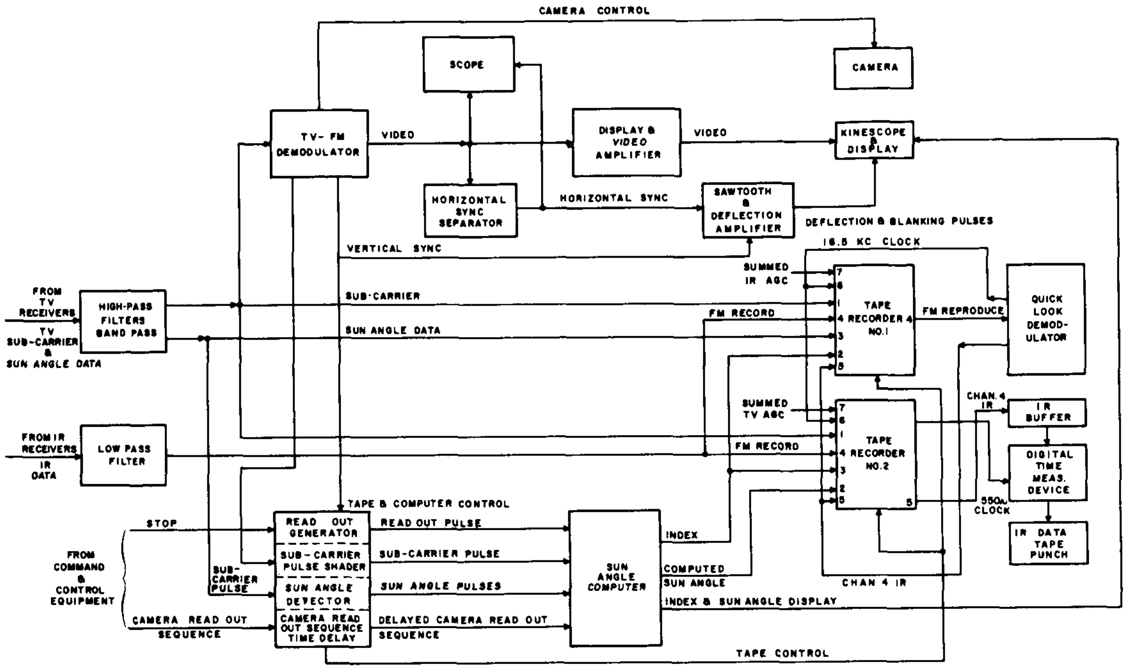


Figure 51. Data Processing and Display Components, Block Diagram

simultaneously, and so that a real time indicator would be in the field of view of the 35-mm camera.

Figure 52 shows the format of the TV pictures and the related identification data. The development, the design, and the operation of the display and video amplifier are described in the TIROS I Final Report (Reference 1).

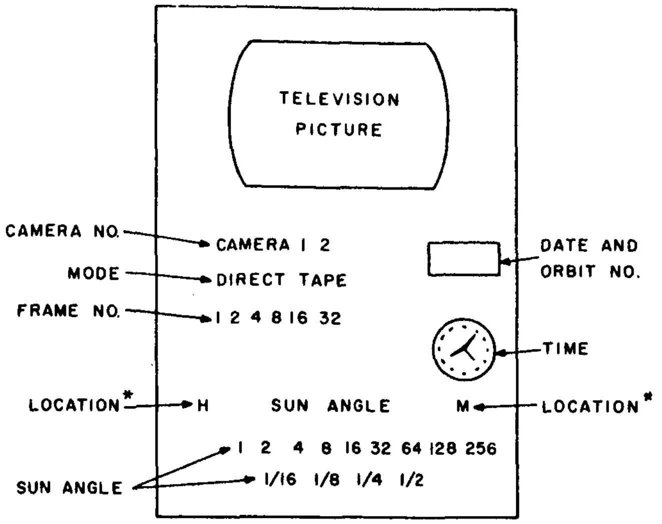
4. Sawtooth and Deflection Amplifier

a. General

The sawtooth and deflection amplifier supplied horizontal and vertical deflection waveforms, and horizontal and vertical blanking pulses to the kinescope of the display and video amplifier.

Functionally, the unit was divided into three circuits; namely, a horizontal sawtooth generator, a vertical sawtooth generator, and a blanking circuit. Except for the unblanking circuit, the unit is identical to the TIROS I sawtooth and deflection amplifier. The unblanking feature was added to increase picture contrast and improve overall picture quality.

Development and design of the sawtooth and deflection amplifier is described in the TIROS I Final Report (Reference 1).



*LOCATION IS INDICATED AS FOLLOWS:
PACIFIC MISSILE RANGE-LETTER "H" AT LEFT
FORT MONMOUTH-LETTER "M" AT RIGHT
PRINCETON -"L" AND LETTER "C" AT RIGHT.

Figure 52. Format of TV Pictures and Related Data

b. Functional Description

Figure 53 is a block diagram of the horizontal sawtooth generator and the unblanking circuit of the sawtooth generator and deflection amplifier unit. Except for RC time constants the vertical sawtooth generator is identical. The horizontal sync pulse inputs drive a one-shot multivibrator whose output pulse width is set to the desired retrace time. The multivibrator output is coupled through a diode clamp and a disconnect diode to the summing point of the operational amplifier. Adjustment controls in the clamp and disconnect circuit provide for control of the retrace slope and also the sawtooth slope. The sawtooth slope determines the picture width.

The d-c amplifier section of the operational amplifier drives two cathode followers. The horizontal limit control adjusts the upper and lower limits of the sawtooth waveforms and thus sets the width of the kinescope display. Sawtooth outputs are applied through the horizontal centering control to the deflection amplifier section of the circuit.

The sawtooth inputs to the deflection amplifier are applied through an isolation emitter follower to the push-pull amplifier which drives the yoke of the kinescope. Phase inversion is obtained by amplifying the emitter feedback of one section of the push-pull amplifier and applying it to the grid of the other section. Balance of the push-pull amplifier is controlled by adjustment of the horizontal balance potentiometer.

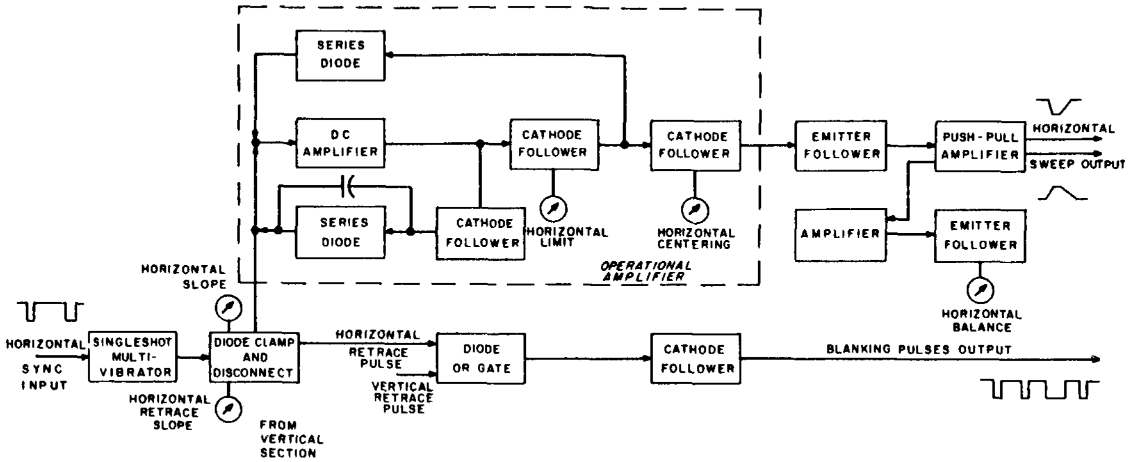


Figure 53. Sawtooth and Deflection Amplifier, Block Diagram

The diode "OR" gate of the blanking circuit receives the retrace pulses from the diode clamp and disconnect circuits of both the horizontal and the vertical sections of the unit. The outputs of the "OR" gate are applied through the isolation cathode follower to the kinescope circuit of the display and video amplifier.

The schematic diagram of the sawtooth generator and deflection amplifier is shown in Figure 54§.

5. Horizontal Sync Separator

The horizontal sync separator provided synchronizing pulses to the horizontal sawtooth deflection circuitry. These pulses were in phase and locked to the prospective video horizontal rate. The operation of the sync separator was unique because it provided these synchronizing pulses in response to video signals which were aperiodic in nature. That is, the horizontal rate or horizontal signal was non-coherent from frame to frame even though the frequency within each frame was the same.

The development, design, and operation of the horizontal sync separator is described in Volume II of the TIROS I Final Report (Reference 1).

§ This illustration is printed on a foldout page located at the rear of this Section.

6. TV-FM Demodulator

a. General

The TV-FM demodulator received the modulated video subcarrier, demodulated the subcarrier, and provided a stable low-impedance video output signal. In addition, this chassis provided the control of the recorder camera shutter and the vertical synchronizing pulses. A pulse counting type of demodulator was selected for use in TIROS because of its stability and because of the linear operating characteristics that it provided. This type of demodulator had been used successfully on commercial video tape recorders in which the relative frequency spectrum relationships of the video signal, carrier, and modulation components were the same as those found in TIROS. The TV-FM demodulator was divided into three sections; namely, the demodulator section, the camera shutter control, and the vertical synchronizing circuits.

The TIROS I evaluation program revealed that the transient behavior of the TV-FM demodulator, with respect to noise and tape drop-outs, had resulted in more picture-quality interference than had been deemed ultimately necessary. Accordingly, design improvements were made in both the demodulator section and the vertical-sync section of the TIROS II TV-FM demodulator.

Initial studies established the following basic requirements for the demodulator section of the TIROS II TV-FM demodulator:

(1) Infinite limiting. Since the demodulator section derived frequency information from the "zero crossings" of the input signal, it had to provide infinite limiting in order to ensure operation to the theoretical threshold. (The characteristics of the counter-type demodulator used in the TIROS system are such that the input carrier-to-noise ratio must be greater than one in order for the unit to be above threshold.)

(2) Symmetrical limiting. Symmetrical limiting was required so that the spectrum of the pulses generated by the "zero crossings" would not fall within the information band and thus would not introduce noise into the demodulator output signal.

(3) Transient response. The transient response of the demodulator section had to be such that the limiting level, and consequently the limiting symmetry, would not be affected by rapid changes in the input level. In particular, the transient response had to be such that the limiting action would not be affected by the 20-db changes in input level which resulted from tape drop-outs.

A review of the characteristics of the TIROS I TV-FM demodulator revealed that the limiting was only 10 db. This resulted in a corresponding 2 db reduction in the carrier-to-noise threshold and a complete loss of signal (white spot) when a tape drop-out exceeded 10 db. The review also revealed that the limiting level, or position, did not remain at the average of the signal, and that transients, such as tape drop-outs, caused the limiting level to change. In order to overcome this difficulty, additional amplifier stages and biased-diode shunt limiters were added to the TIROS II circuitry. The diodes used in the shunt-limiter circuits were chosen so that changes in voltage or current level would have very little affect on the diode capacitance. Because of this selection of diodes, changes in limiting level due to changes in input level were eliminated. The overall effect of the additional amplifier stages and limiters was to increase the limiting, from the TIROS I level of 10 db, to approximately 40 db. In addition to the increase in limiting, the TIROS II circuitry provided linear phase response between 18 kc and 120 kc, and showed no apparent change in limiting level for 20-db step modulation of the input signal.

In order to prevent the generation of false vertical sync pulses, modifications were also made to the TIROS II circuitry to improve its noise immunity. The vertical-synchronizing section of the TIROS I TV-FM demodulator developed vertical-sync pulses by envelope detection of the 70-kc to 100-kc band of the demodulator input. This method of developing the pulses would have been satisfactory if the signal input had had a low noise content and if there had been no tape drop-outs. However, since the noise power-density was often equal to or greater than the signal power-density in the 70-kc to 100-kc band, vertical sync pulses were sometimes generated in response to noise inputs.

The design modifications for the TIROS II circuitry was based on the concept of deriving the vertical-sync pulses from the 250-pps horizontal-sync pulses. The modified circuitry included a narrow-band filter, which rejected all frequencies except the 100-kc horizontal-sync component of the input signal, and a stagger-tuned amplifier which was centered at 250 cps. Although noise inputs were expected to occasionally provide a power density at 100 kc that would be equivalent to the horizontal-sync pulse, the repetition rate would not be 250 pps. Therefore, the extraneous 100-kc signals could not pass through the amplifier.

The bandwidth of the stagger-tuned amplifier was such that only 3 lines of picture video would be lost before the amplifier output would have sufficient amplitude to trigger the vertical-sync pulse generator. By employing both the narrow-band filter and the stagger-tuned amplifier, the circuit was made immune to the noise inputs that, during TIROS I, had resulted in "false" vertical sync pulses.

b. Functional Description

The block diagram of the TV-FM demodulator is shown in Figure 55. The input signal is an FM subcarrier whose frequency varies between 70 kc and 100 kc, and which has a modulating spectrum of from 0 kc to 62.5 kc. The duration of each FM input is two seconds, the time required for one TV picture. Timing for the camera shutter, vertical sync, and subcarrier indication signal is initiated when the FM signal is received.

The amplitude of the FM input signal is approximately 3 volts peak-to-peak. This signal is applied through interleaved clipper and amplifier stages to provide the required 40 db of limiting. The output of the final clipper stage, a 1-volt peak-to-peak signal, is applied through the cathode-coupled limiter to the 1.25-microsecond shorted delay line. The output of the delay line, positive and negative 2.5-microsecond pulses whose pulse rate is directly proportional to the input frequency, is applied to the phase inverter. The equal-amplitude, opposite-polarity outputs of the phase inverter are applied to the full-wave plate detector. The output of the plate detector, is applied through the loss-pass

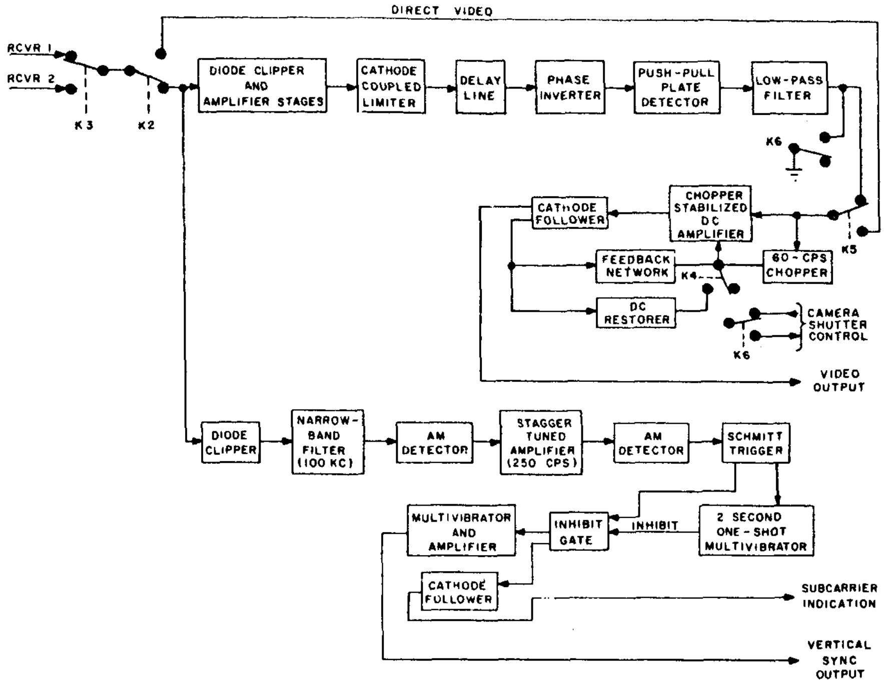


Figure 55. TV-FM Demodulator, Block Diagram

filter to the chopper-stabilized d-c amplifier. The filter, which has a flat response between 0 and 62.5 kc, serves as an integrator to establish a video signal whose level changes at a rate corresponding to the modulation frequency. Feedback from the output cathode follower reduces the overall gain of the d-c amplifier to approximately 10. The video output of the unit is applied to the sawtooth generator and deflection amplifier.

Relay K6 shorts the input to the d-c amplifier in the absence of the carrier to prevent noise feed through. Direct video can be fed into the d-c amplifiers for test purposes. The d-c restorer provides d-c restoration for the direct-video input. Relays Kl through K5 provide for all necessary switching functions; these relays are operated from the monitor control panel.

Timing of the camera shutter, and the vertical-sync and subcarrier indication pulses are provided when the FM input is received. The FM input signal to the vertical-sync circuit is passed through the diode clipper and applied to the narrow-band filter which is tuned to 100 kc. The 100-kc horizontal-sync components of the FM signal pass through the filter and are detected by the AM detector. The output of the detector, the envelope of the 250-pps horizontal-sync signals, is applied to the stagger-tuned amplifier. The output of the amplifier circuit is a 250-cps sinewave. This signal is amplitude detected and then applied to Schmitt-trigger circuit. Characteristics of the circuitry are such that after approximately 3 lines of the FM input (three horizontal-sync pulses) have been received, the level of the detector output rises above the Schmitt-trigger threshold.

The output of the Schmitt-trigger is applied: (1) to the 2-second multivibrator; and (2) through the inhibit gate to the vertical-sync multivibrator and the subcarrier-indication cathode follower. The 2-second, inhibit-pulse, output of the 2-second multivibrator ensures that only one output of the Schmitt-trigger circuit can be applied through the inhibit gate during any two-second interval. This action prevents false triggering of the Schmitt-trigger, which might be caused by momentary signal drop outs, from resulting in false vertical-sync pulses.

The subcarrier-indication output is applied to the tape and computer control. The 10-microsecond, negative-going, vertical-sync output is applied to the sawtooth generator and deflection amplifier.

Figure 56§ is the schematic diagram of the TV-FM demodulator. A detailed description of circuit operation is given in Volume II of the TIROS I Final Report (Reference 1).

7. Tape and Computer Control

a. General

The tape and computer control detected the sun-angle tone bursts, shaped the envelope of the detected video subcarrier, provided the source signals for frame identification, provided a central control for the two tape recorders, and provided the readout pulse for the sun-angle computer. Except for the sun-angle burst detector and the subcarrier envelope-shaping network, the design of the circuits within the tape and computer control was the same as for TIROS I and is described in the TIROS I Final Report (Reference 1).

The redesign of the sun-angle tone detector was necessary to reduce the noise content of the detected sun-angle output*. The basic approach in this redesign was to pass the sun-pulse input through a narrow pass filter to remove the noise components. Since a narrow pass filter, centered at 10 kc, would require an extremely high Q, it was decided to first reduce the frequency of the sun-pulses to 1-kc by heterodyning them with the output of an 11-kc Colpitts oscillator. This reduction in frequency resulted in a corresponding decrease in the Q requirement of the filtering network.

Initially the filtering network was designed to pass 1-kc ±25 cps; however, subsequent system testing showed that the sun-pulse frequency occasionally drifted from these bounds. Accordingly, the filtering network was modified slightly (by changing the coupling capacitor) to increase its bandwidth to 100 cps. Although this modification resulted in a slight shift in the filter's center frequency, it was easily compensated for by adjusting the tuning coil of the Colpitts oscillator until the difference frequency of the heterodyning process was 980 cps instead of 1000 cps. Figure 57 shows a typical response for the filtering network.

*An evaluation of TIROS I operations showed that noise pulse inputs to the sun-angle computer resulted in the misinterpretation of sun-pulse duration and sequence. This, in turn, resulted in erroneous sun-angle computations.

§ This illustration is printed on a foldout page located at the rear of this Section.

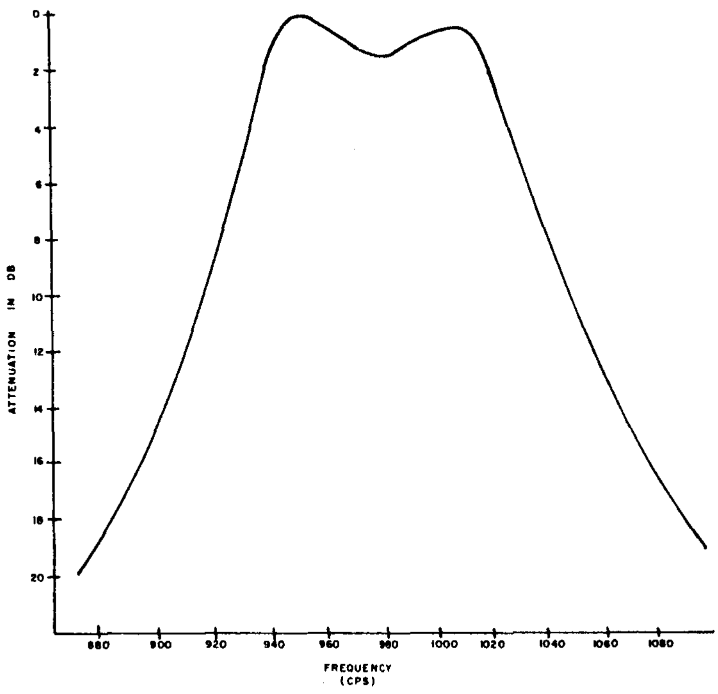


Figure 57. Tape and Computer Control, Filter Response

The redesign of the subcarrier pulse circuit was made as a companion change to a modification which was made in the TV-FM demodulator. The combined effort of both changes was to reduce the noise content of the detected video subcarrier inputs to the sun-angle computer. The function of the tape and computer control in this modified system was to shape the detected subcarrier envelope and to provide a suitable output impedance for driving the sun-angle computer. A Schmitt-trigger was selected for the pulse shaper and a cathode follower was selected as the driving element.

b. Functional Description

Figure 58 is a block diagram of the tape and computer control. Functionally, the unit is divided into five main sections; namely, the sun-angle burst detector, the sub-carrier-envelope shaper, the readout-pulse shaper, the direct and playback picture-source circuit, and the tape control circuits.

The sun-angle burst detector receives a sun-angle input, consisting of short, medium, or long 10-kc bursts in various combinations with each other, and delivers pulses, which have the durations as the burst inputs, to the sun-angle computer. Each sun-angle burst input is applied through the noise clipping network, amplified, and applied to the diode mixer. Heterodyning takes place with the output of the 11-kc ±1-kc Colpitts oscillator and the difference frequency (980 cps) is applied to the bandpass filter. The filter

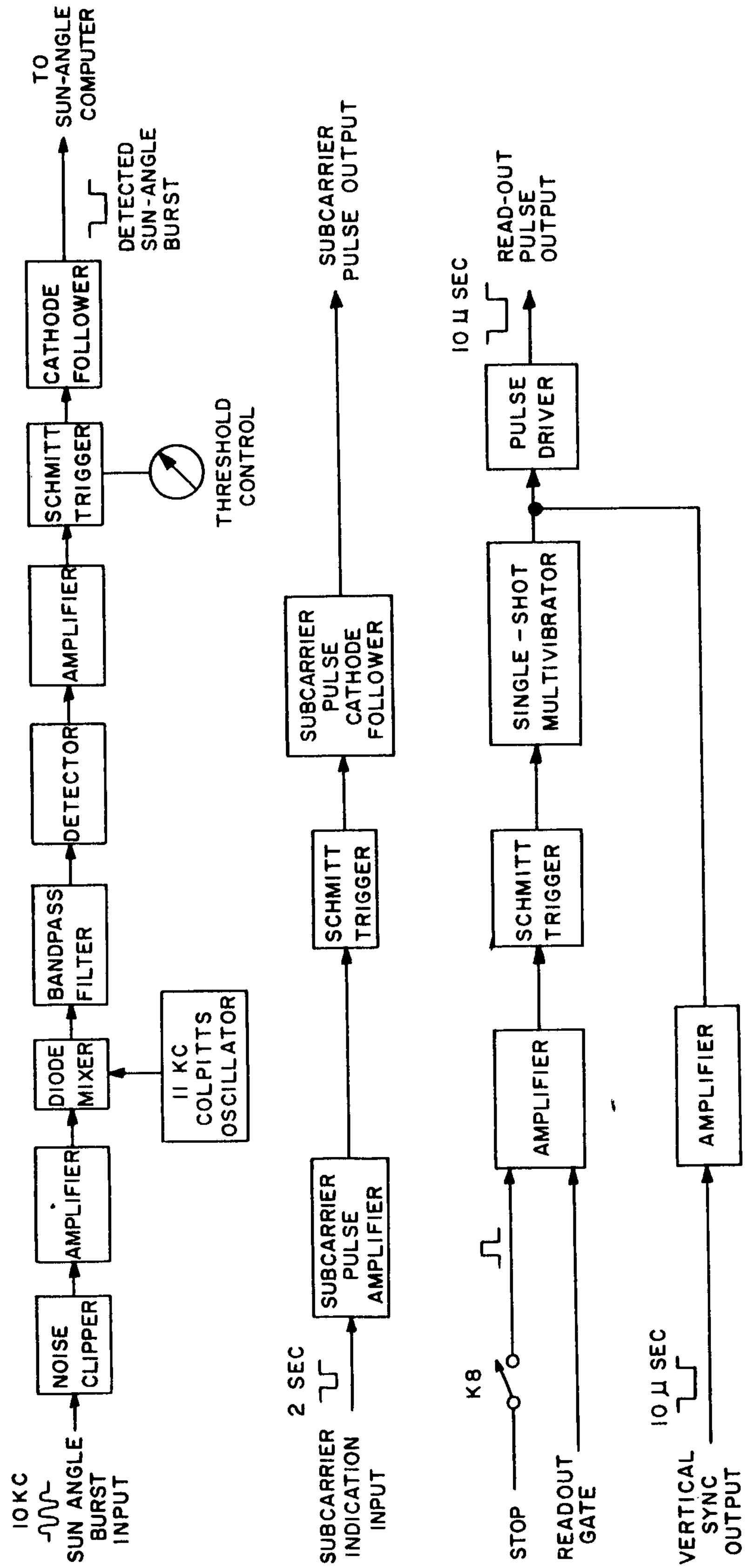


Figure 58. Tape and Computer Control, Block Diagram (Sheet 1 of 2)

Figure 58. Tape and Computer Control, Block Diagram (Sheet 1 of 2)

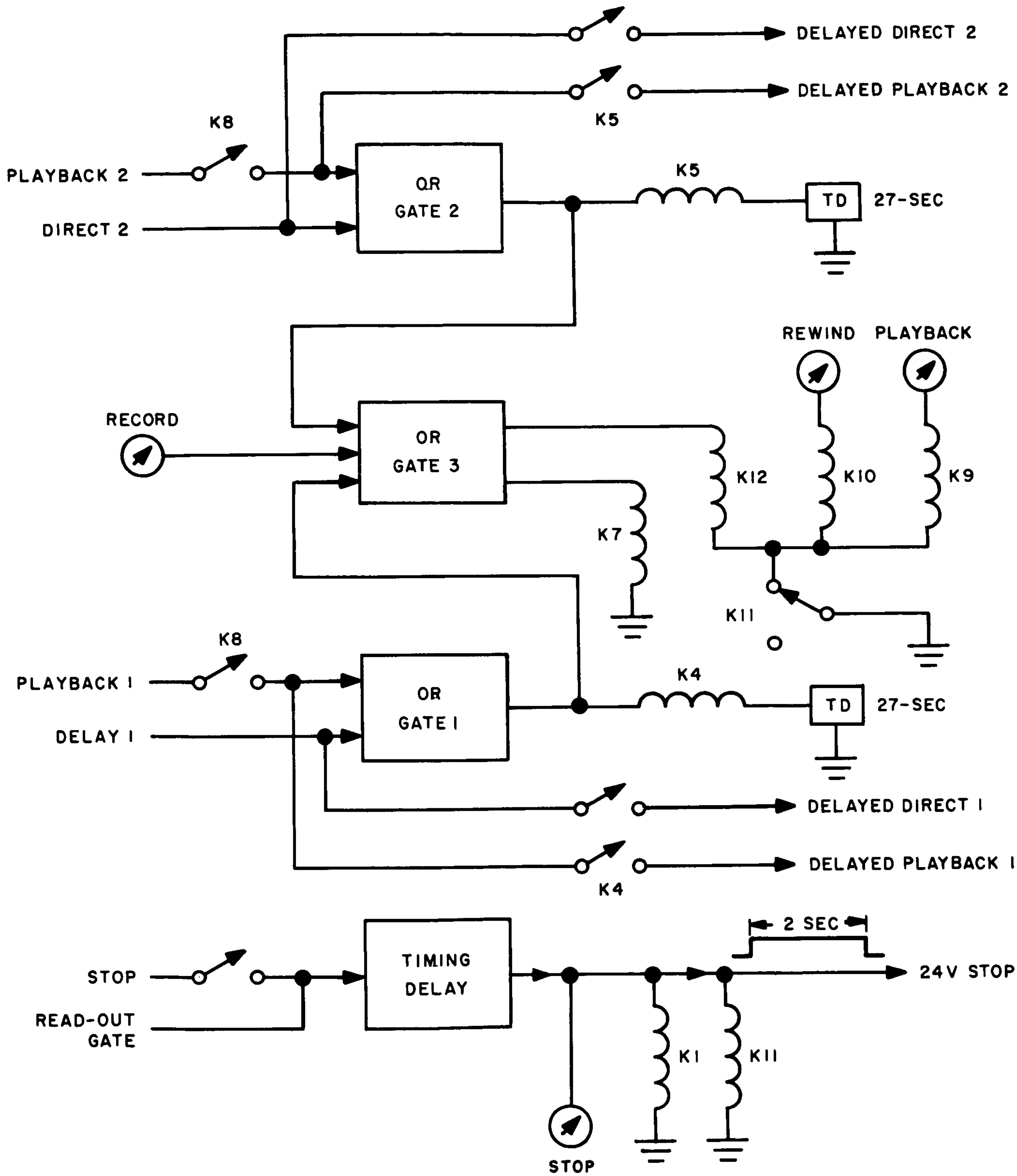


Figure 58. Tape and Computer Control, Block Diagram (Sheet 2 of 2)

greatly attenuates frequencies outside the 930 to 1030 cps range and thus eliminates most of the noise components of the signal. Action of the narrow-band filter is such that it imparts rise and decay times of approximately 10 milliseconds to the signals.

The filter outputs are rectified, filtered, and amplified to produce pulses having the same duration as their corresponding 10-kc sun-angle bursts. These pulses are then applied to the Schmitt-trigger circuit and result in negative-going pulses at the output of that stage. The threshold control determines at what points, on the 10-millisecond leading and trailing edges of the detected pulses, the Schmitt-trigger will turn on and off. Nominally, when the amplitude of the accompanying noise is less than one-half of the signal amplitude, the threshold control is adjusted so that the Schmitt-trigger turns on at the mid-point of the detected pulse. However, the setting can be raised during periods of heavy noise to prevent accidental triggering of the Schmitt circuit. The output pulses from the Schmitt-trigger are applied through a cathode follower to the sun-angle computer.

Figure 59 shows the basic time relationships of the sun-angle burst inputs, the filtered detected pulse, and the output of the tape and computer control. From this figure it can be noted that the rise and decay time imparted by the narrow-band filter causes a slight shift (nominally 5 milliseconds) in the time base of the detected sun-angle burst. This nominal shift causes an error of less than one degree in the computed sun-angle and is normally considered negligible. However, since this error is a constant, it can be easily compensated for when and if the sun-angle must be determined more accurately.

The subcarrier shaper receives 2-second negative-going subcarrier pulses from the TV-FM demodulator. After amplification, the subcarrier pulses are applied to the Schmitt-trigger circuit. The Schmitt-trigger sharpens the leading and trailing edges of the 2-second pulses which are then fed through a biasing network to the cathode follower. The cathode of the cathode follower is connected to a dividing network which causes the output pulses to swing between a slightly positive level and approximately -10 volts. A zener network then limits the pulse swing between the required 0 and -8 volts. These limited pulses are applied to the sun-angle computer. The low output impedance of the cathode follower ensures efficient driving of the computer input circuit.

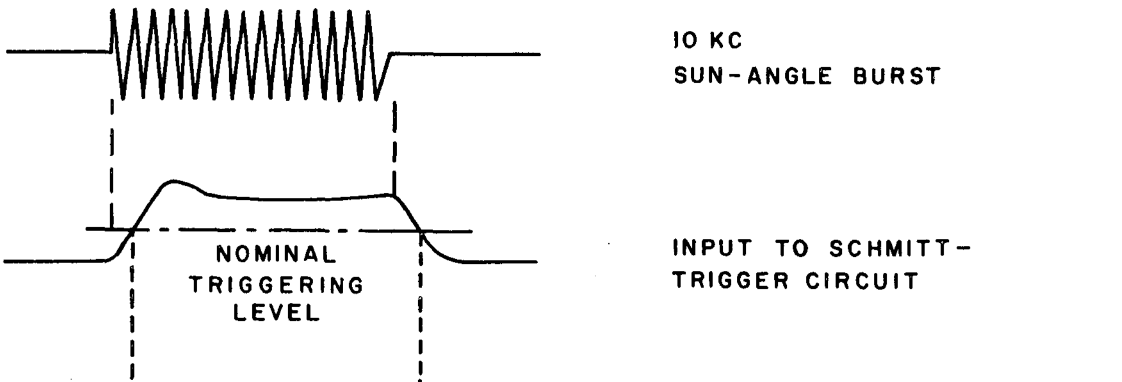


Figure 59. Tape and Computer Control Waveforms

The read-out pulse circuit receives one of two inputs; namely, a stop signal from the command programmer or a read-out gate signal from the sun-angle computer. The signal that is present is amplified and applied to the Schmitt-trigger circuit. The output of the Schmitt-trigger circuit, a negative trigger pulse, triggers the single-shot multivibrator to produce a positive-going, 10-microsecond pulse. This pulse is applied to the pulse driver which produces the read-out pulse for the sun-angle computer. The read-out pulse can also be produced by a vertical sync input from the TV-FM demodulator. This input is amplified and then applied to the pulse driver.

The direct and playback circuit receives any one of the direct and playback signals, delays the input signal for 27 seconds, and then applies the signal to the sun-angle computer as a source signal. When either a "direct" or a "playback 1" signal is received, the signal is applied through OR gate 1 to relay K4. Twenty-seven seconds later, the relay energizes and applies the signal to the sun-angle computer. Similar action occurs when "direct 2" or "playback 2" is applied to OR gate 2.

An output from either OR gate 1 or 2 will pass through OR gate 3 and energize relays K7 and K12. When relay K12 energizes, a RECORD indicator lamp lights; when relay K7 energizes, a start signal is sent to the tape recorders.

The tape control circuit controls the start, stop, rewind, and playback functions of the tape recorders. Switch S1 can be used to start the recorders when a direct or playback signal is not present. STOP, REWIND, and PLAYBACK switches are provided for manually controlling each of those functions. Figure 60§ is the schematic diagram of the tape and computer control.

8. Monitor Control

The monitor control provided switches and relays for controlling the inputs of the data processing and display components, and for turning on and off the 32-volt power supply, the three 300-volt power supplies, the high voltage power supply, and the sun-angle computer power supply. This unit was identical to the monitor control employed in the TIROS I system.

9. Sun-Angle Computer

The sun-angle computer was designed to: (a) compute the sun-angle for each TV picture; (b) provide an index for each photograph; (c) provide a display of computed information for photographic recording and an indexing signal for recording on the instrumentation recorder; and (d) provide the display for playback of data from the instrumentation recorder and a means for selecting readout of single video frames. Except for a slight modification in the sun-angle computing circuit, which was aimed at increasing reliability through circuit simplification, the TIROS II unit was identical to the TIROS I sun-angle computer.

§ This illustration is printed on a foldout page located at the rear of this Section.

The basic equation used for computing the sun-angle was:

$$\theta = 40n - 40t_a/t_b$$

where

40n indicates which section of satellite is facing the sun

t_a is the time interval between the start of the video subcarrier and the leading edge of the first sun pulse

t_b is the time interval between the leading edges of the first and second sun pulses and is equivalent to the time required for the satellite to rotate 40 degrees

Since the t_b interval was directly related to the satellite's spin rate, and since the spin rate would remain nearly constant for a given orbit, it was concluded that the t_b data could be fed into the computer as fixed data. To implement this, the t_b counter circuitry of the TIROS I system was replaced by a bank of twelve switches. Use of these switches permitted the t_b time interval to be calculated in advance and set into the computer in binary form.

The equation used for determining the t_b time interval was:

$$N = \frac{S}{9}(4000) = 444S$$

where

N is the t_b interval which is to be set into the binary coded switches

S is the satellite's spin rate

Figure 61 is that portion of the sun-angle logic diagram which was affected by this change. A discussion of the development, design, and functional operation of the sun-angle computer, and the unchanged portion of the logic diagram is contained in Volume II of the TIROS I Final Report (Reference 1). A detailed analysis of circuit logic is presented in "Operating and Instruction Handbook, TIROS II Meteorological Satellite System" (Reference 4).

10. Calibrator

The calibrator unit generated a video test pattern and an 85-kc FM subcarrier, which were used to test the television subsystem, and simulated sun-angle bursts, which were used to test the sun-angle computer. Functionally, the TIROS II calibrator was the same as the TIROS I unit. The functional diagram of the calibrator is shown in Figure 62.§ The discussion of the design philosophy and the functional description given for the TIROS I calibrator in Volume II of the TIROS I Final Report (Reference 1) is also applicable to the TIROS II unit.

§ This illustration is printed on a foldout page located at the rear of this Section.

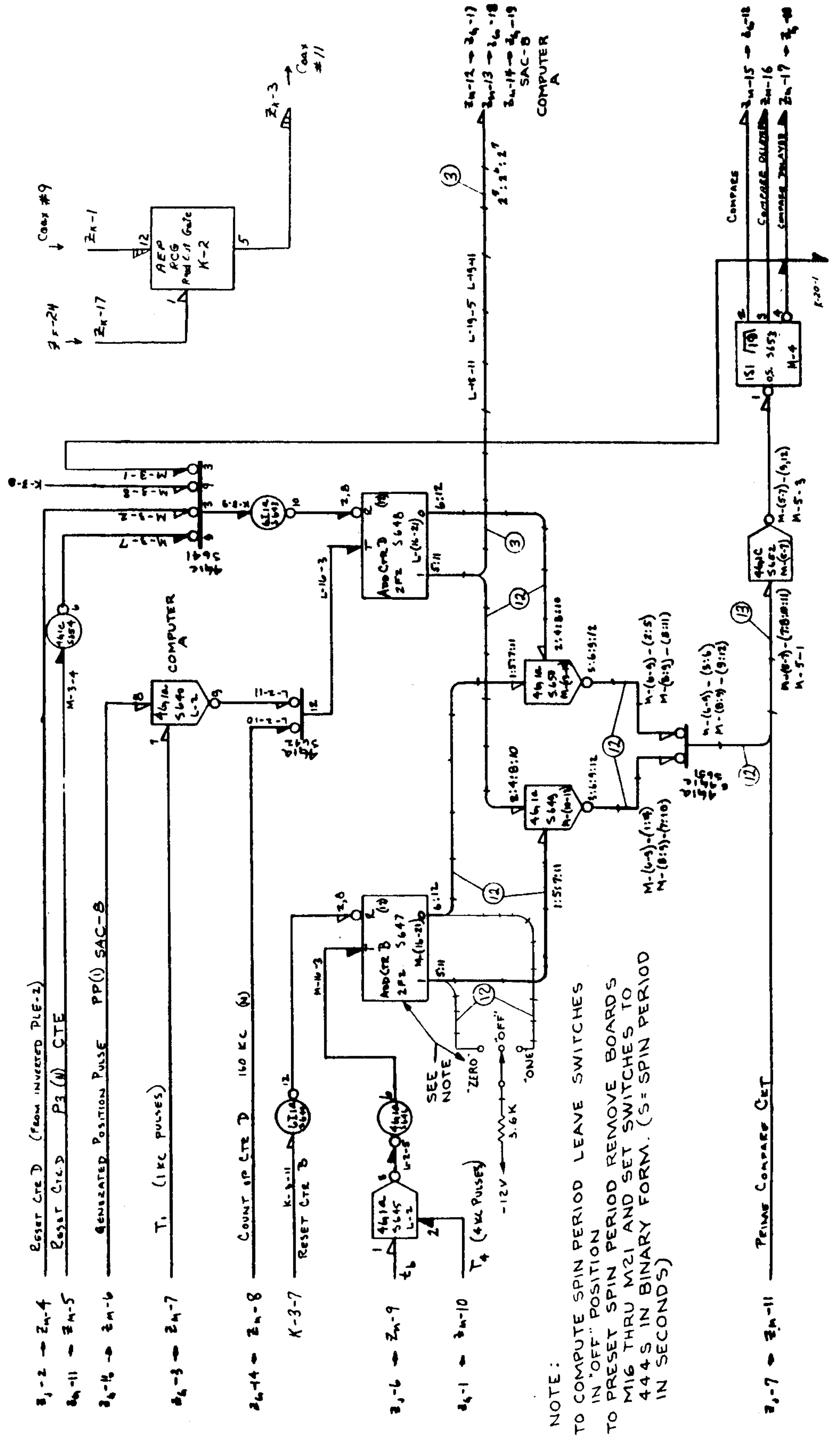


Figure 61. Sun-Angle Computer, Modified Portion of Logic Diagram

11. Attitude Pulse Selector

a. General

The attitude pulse selector received the "raw" attitude signals from the Sanborn recorder, selected and reformed the valid attitude pulses while blocking any spurious pulses, and applied the valid attitude pulses to the digital time measuring device (DTMD).

Inclusion of the attitude pulse selector in the TIROS II system was part of the general redesign of the attitude indicator subsystem. The need for this redesign was indicated by an evaluation of TIROS I attitude data which showed that the oversensitivity of the horizon sensor had resulted in spurious attitude pulses during the earth-portion of many scans. In order to overcome the effect of this oversensitivity, it was decided to transmit the attitude data in analog form* and to make selection of the valid pulses at the interrogating ground station.

The design of the attitude pulse selector was greatly influenced by the limited time schedule; component design was often determined by availability rather than by optimum design considerations. The selected design employed a variable length time gate which was initiated by each sky-earth transition, and which inhibited the output of the attitude pulse selector until approximately 50 milliseconds before the succeeding earth-sky transition was expected. Since it was known that the earth period would vary, the circuit was designed so that the duration of the inhibit gate would automatically track any changes in the earth-period of the scan.

In order to accommodate variations in earth period due either to changes in the satellite's attitude or to changes in the spin rate, the inhibit gate was made variable between 0.5 second and 3.5 seconds. The lower limit of 0.5 second was set after analysis indicated that the attitude data received for earth periods of less than 0.5 second would loose its validity. (This loss of validity would be due to the increased rise times that are experienced as the field angle of approach to the surface of the earth gets smaller.)

Tracking action of the inhibit gate duration was accomplished by use of a bidirectional stepping motor which was coupled to the shaft of a servo-potentiometer through a friction clutch. For reasons of simplicity, a relay type servo was designed which lengthened or shortened the inhibit gate by a fixed amount each time that a set of sky-earth and earth-sky transitions was received. Although this type of circuit caused the inhibit gate's duration to oscillate about the desired period rather than to lock precisely to it, the circuit was considered adequate for the task. Also the use of this type circuit was justified in that the lack of "dead" zone permitted the use of simple logic.

*The TIROS I attitude data was transmitted to the ground station in digital form, with selection of valid attitude pulses being made by a satellite-borne circuit. Whenever this circuit was accidentally triggered by a spurious attitude pulse (cloud transition) the circuit would block the succeeding valid-attitude pulse (earth-sky or sky-earth transition).

The time change for each step of the relay-type servo was set at 15 milliseconds; this resulted in a sufficient tracking rate for the range of interest. This short time-step permitted the inhibit gate to be terminated near the leading edge of the earth-sky transition while still insuring against the loss of track.

b. Functional Description

Figure 63§ shows the block diagram of the attitude pulse selector. Inputs to the attitude pulse selector are routed through the emitter follower to the two Schmitt-trigger circuits by the selector switch. Input bias adjust R83 controls d-c level at the emitter of the emitter follower and thus also affects the triggering level of the two Schmitt triggers.

The sky-earth Schmitt circuit triggers only when a negative input is received and is, therefore, not affected by the earth-sky pulses. Conversely, the earth-sky circuit triggers only when a positive input and is not affected by the sky-earth input. Level controls R2 and R6 regulate the sensitivity of the two Schmitt-trigger circuits.

The output of the sky-earth Schmitt trigger is applied through one differentiator to inhibit gates 1 and 2, and through a second differentiator to the inhibit gate generating circuit. The output of the earth-sky Schmitt trigger is applied through a differentiator to inhibit gate 3 and through an amplifier to the inhibit gate generator. The sky-earth and earth-sky pulses are applied through their related output circuits to the output of the unit.

The repression of spurious pulses is accomplished by means of the inhibit gate generator. The output of this circuit is applied to inhibit gates 1, 2, and 3 and blocks all outputs during its existence. The inhibit gate is initiated by the sky-earth transition and is: (1) applied through an emitter follower to the inhibit gates; and (2) differentiated and applied to the 50-millisecond one-shot multivibrator. If the earth-sky transition occurs before the end of the 50-millisecond period, the earth-sky pulse is applied through AND gate 1 and its associated emitter follower to the motor control. The effect is to decrease the inhibit gate's duration by 15 milliseconds. If the earth-sky transition occurs after the 50-millisecond pulse terminates, the transition pulse is applied through inhibit gate 4 and its associated emitter follower to the motor control. The effect in this case is to increase the duration of the inhibit gate by 15 milliseconds. By use of this logic loop the duration of the inhibit gate is made to oscillate (±15 milliseconds) about a point which is 50 milliseconds less than the actual earth scan.

12. Quick-Look Demodulator

The quick-look demodulator and its peripheral equipment are government furnished. This equipment, which was mounted in equipment rack 20, is illustrated in Figure 64.

The quick-look demodulator derives outputs, which are used to determine satellite attitude and spin rate, from the channel 4 IR data transmitted by the satellite. Determination of the satellite's attitude is made possible by the events output of the quick-look demodulator; the sun-pulse outputs from the unit are used for determining the satellite's spin

§ This illustration is printed on a foldout page located at the rear of this Section.

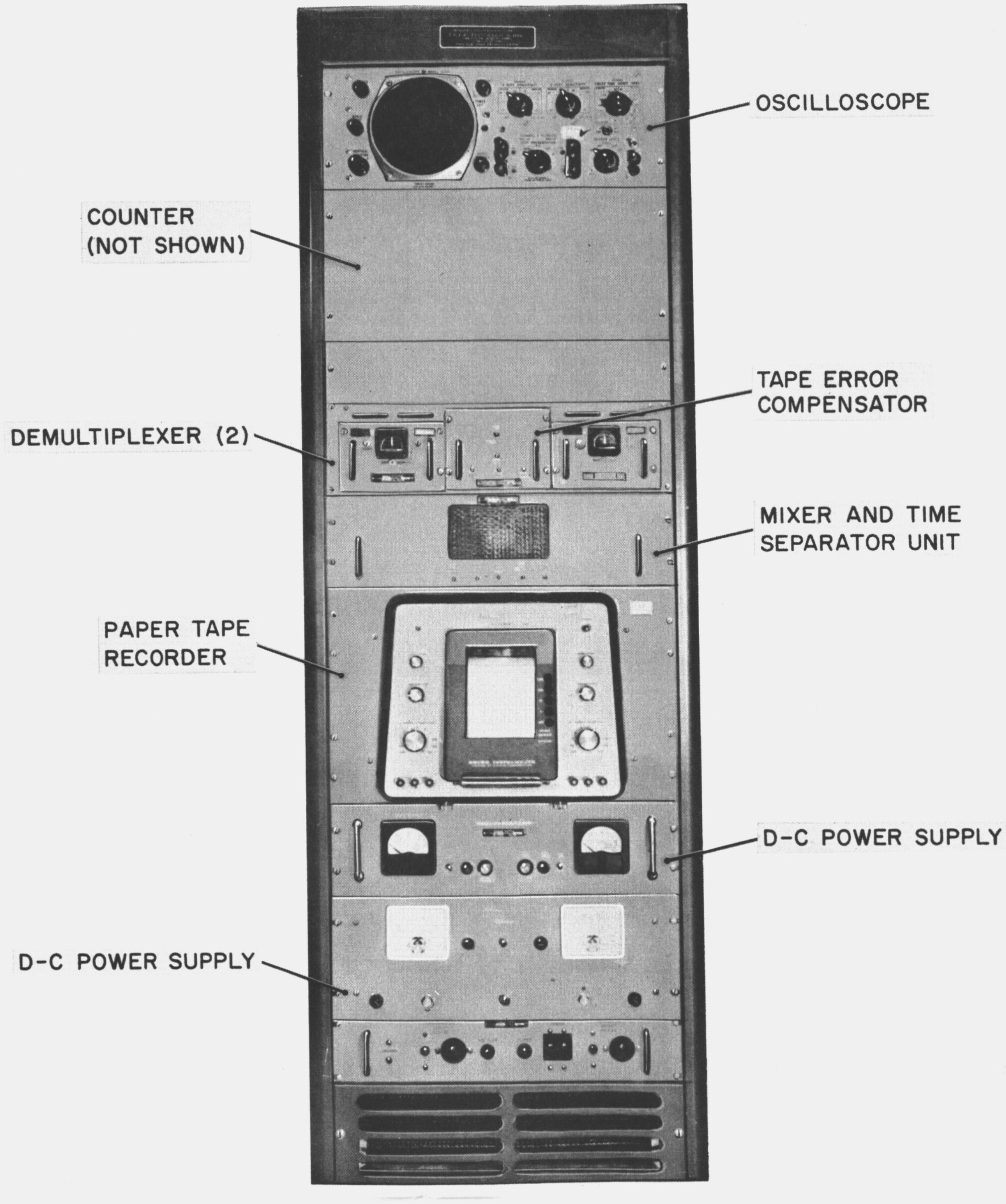


Figure 64. Quick-Look Demodulator

rate. A 16.5-kc output from the unit is applied to the ground station tape recorders as a time reference.

Reference 3 contains a detailed description of circuit operation as well as the calibration and checkout procedures for the quick-look demodulator.

13. Infra-Red Buffer

a. Introduction

The infra-red (IR) buffer accepted the signals from channels 5 and 6 of the instrumentation tape recorder at the playback rate of 3-3/4 inches per second. Using these inputs, the IR buffer generated signals that were suitable for driving the DTMD.

The input signal characteristics and the output signal requirements for the IR buffer are listed in Reference 4. The channel 5 data consisted of a squarewave which had an irregular period and duty cycle, and relatively high hum and noise levels. Since the significant information was embodied in the timing between the successive transitions (or events) of the squarewave, it was concluded that most of the extraneous disturbances could be eliminated by use of a Schmitt-trigger circuit. D-c level controls were included in the circuit to allow adjustment of the waveform level at which the Schmitt-trigger changed state.

Two outputs, of opposite polarity, were taken from the channel 5 Schmitt-trigger circuit to provide for the "trigger" output and "sense" output requirements. Standard differentiators and driving circuits were used to establish the pulse characteristics. In order to establish the correct time relationship of the "sense" and "trigger" outputs, a several millisecond delay circuit was added to the "sense" output circuit.

A standard amplifier circuit was included in the IR buffer to process the 1032-cps timing signal before it was applied to the DTMD. Detection of "end-of-tape" pulses (momentary drop-outs of the timing signal) was achieved by use of a full wave detector. A Schmitt-trigger circuit was used to sense any decrease in the output of the detector (signifying a signal drop-out) and, in response, to generate the start/stop pulse required by the DTMD.

b. Functional Description

A block diagram of the IR buffer is shown in Figure 65. The events input signal derived from playback of Channel 5 of the Ampex recorder is amplified and applied to the Schmitt-trigger circuit. The Schmitt-trigger outputs, squared waveshapes of both polarites, are differentiated so that one or the other polarity produces a positive pulse at each transition of the events signal. When the "signal" switch is in the "on" position, these positive pulses are applied through the OR gate to the output pulse driver to produce the trigger-output signal. The polarity of the Schmitt-trigger output that has a positive-going transition at the time of a "sky-earth" event is delayed and differentiated. The resulting positive pulse is applied to the output stage which generates the sense-output pulse.

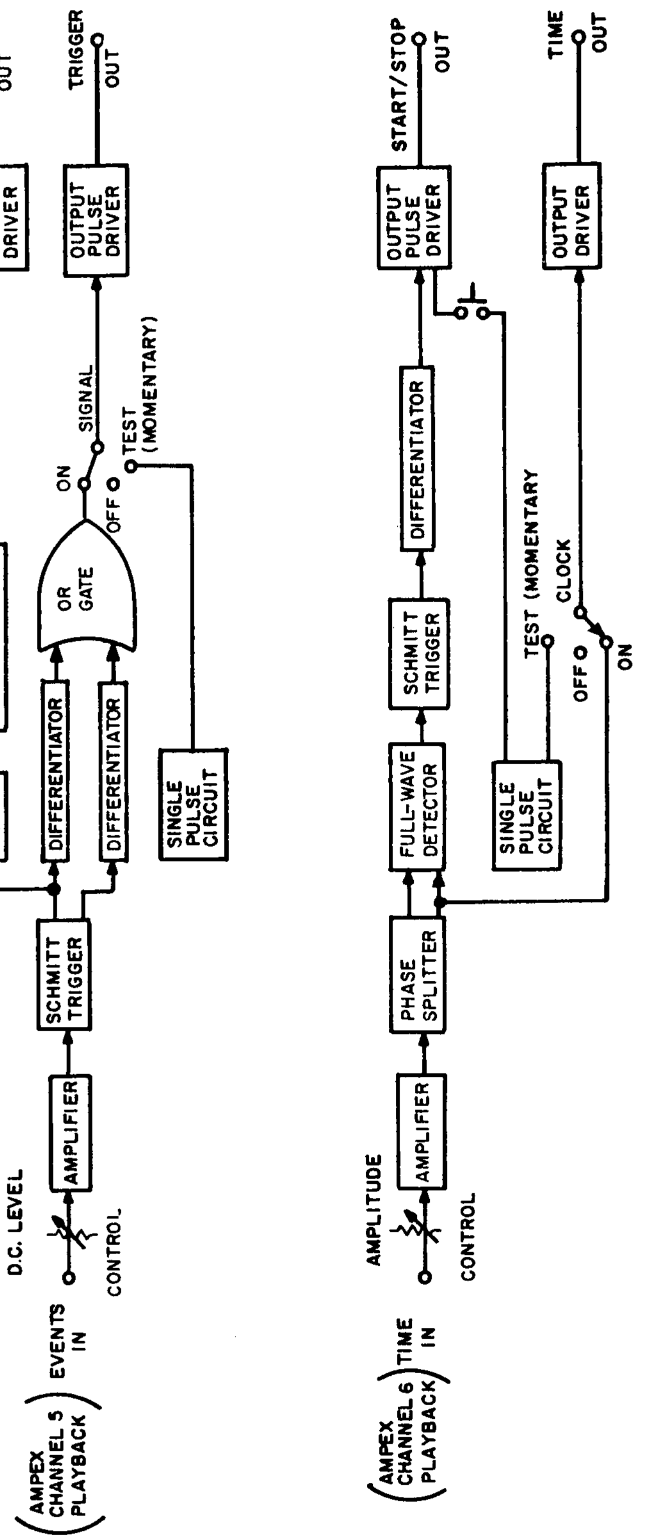


Figure 65. IR Buffer, Block Diagram

The time-input signal (approximately 1030 cps), derived from playback of channel 6 of the Ampex recorder, is amplified and applied to the phase-splitter circuit. The outputs of the phase-splitter are full-wave detected, and the resulting d-c is applied to the Schmitt-trigger circuit. An end-of-tape dropout in the time-input signal causes the Schmitt-trigger to return to the "off" state and thus to form the start/stop-output pulse.

When the "clock" switch is set to "on," one of the phase-splitter outputs is applied through the output driver to the time output.

The schematic diagram of the IR buffer is shown in Figure 66.§ For a detailed description of circuit operation, refer to "Instruction and Operating Handbook, TIROS II Meteorological Satellite System" (Reference 4).

14. Digital Time-Measuring Device

a. Introduction

The addition of the IR subsystem to the TIROS II satellite established the requirement for "quick-look" demodulation of the channel 4 IR date (I-4) and for reduction of that data to a teletype punched tape format. The recovery of "quick-look" data at the CDA station was accomplished in two phases. The first phase involved demodulation of the I-4 subcarrier, and the recording of the resultant "events" signals and time-reference signals on the instrumentation recorder. The second phase of the recovery operation consisted of slow-speed playback of the tape recorder, measurement of the time interval between the "events" signals and the time-reference signals, and the conversion of these measurements to punched-tape format.

The first phase of data recovery was performed by the quick-look demodulator which was supplied to RCA as government-furnished equipment. The second phase of recovery was similar to the function performed by the elapsed time counter-scanner in reducing the TIROS I horizon-sensor (H-1) data. Because of the similarity in the two functions, it was decided to modify the existing elapsed time counter-scanners so that they could be used for handling both the H-1 data and the I-4 data. After these modifications were completed, the unit nomenclature was changed to "digital time-measuring device" (DTMD).

Two DTMD's were installed at each CDA station (one for I-4 data* and one for H-1 data). In the event of a failure in one unit, the other unit could be used in both applications. Since punched-tape reduction of H-1 data had to occur immediately upon receipt of the input from the satellite, while the reduction of I-4 data would not occur until between-pass playback, this dual use of a single unit could be accomplished without the loss of either type of data. Thus the interchangeability of the two DTMD's provided greater reliability for both functions.

* In order to make the I-4 data compatible with the DTMD's input requirements, an IR buffer unit was included at each CDA station. Descriptions of the design, the development, and the operation of this unit are contained elsewhere in this report.

§ This illustration is printed on a foldout page located at the rear of this Section.

b. Description of Modifications

The basic modifications and additions which were required to convert the TIROS I elapsed time counter-scanner into the TIROS II digital time-measuring device are as follows:

(1) A change in print-out format that would reduce the length of the hard copy by allowing several readings to be printed on each line.

(2) An increase in operating speed so that, with four I-4 "events" per spin period of the satellite, a playback speed-up ratio of 30 to 16, and a 15-rpm spin rate, a single-event readout would be achieved in less than 0.53 seconds.

(3) The inclusion of an extra character in each readout to provide "event" polarity and thus to facilitate the differentiation between sky-earth and earth-sky transitions.

(4) The inclusion of an automatic start/stop circuit which would cause the DTMD to stop upon receipt of the I-4 data's real-time reference (end-of-tape pulse) and thus provide a readout that would represent the time of occurrence of the reference.

The reduction of hard-copy length was achieved by providing ten readouts per line as opposed to the one readout per line used in TIROS I. This format was selected because it provided compatibility with NASA data-analysis computer programs, and because it provided ease of implementation. Each of the first nine readouts consisted of four digits which were followed by either a space or a comma to indicate event polarity.* In the tenth readout of each line, the four basic digits and the space or comma were suffixed by "carriage return," "line feed," and "figures."

This change in format was implemented as follows:

(1) A separate input connector and three additional bi-stable multivibrators (flip-flops) were added to the DTMD to accommodate event-polarity inputs. The presence of a pulse at the input connector initiated circuit operation that caused a comma to be punched in the corresponding readout. Conversely, the absence of a pulse at that point caused a space to be punched in the corresponding readout.

(2) An additional stage of the shift register was put into use to provide the time required to punch the additional character (space or comma) that was used to signify event polarity.

(3) An additional logic circuit was installed to generate an "end-of-scan" immediately following the space or comma of each of the first nine readouts of a line. This logic bypassed the "carriage-return" and "line-feed" by resetting the

* A comma in a readout was used to indicate that the count was accumulated during a "sky" interval and was terminated by a sky-to-earth event. Conversely, a space was used to indicate that the count was accumulated during an "earth" interval and terminated by an earth-to-sky event.

shift register to its initial state. The "figures" character was eliminated from the first nine readouts of each line by using the "end-of-scan" output pulse to reset the "figures" one-shot multivibrator before it could gate the outputs to the punch driving relays.

(4) One of two divide-by-ten cards, which was eliminated from the punch timing circuit, was modified and used to count the readouts on each line. On the tenth readout of a line, the divider circuit inhibited the "end-of-scan" (described in item 3) and thus allowed the shift register to complete its full cycle with "carriage-return," "line-feed," and "figures."

The increased-speed requirement was satisfied by increasing the tape-punch rate from the TIROS I rate of 10 characters per second to 20 characters per second, the maximum rate recommended by the manufacturer. This increased tape-punch rate provided a punch-out time of 0.25 seconds for the first nine readouts of a line and of 0.40 seconds for the tenth readout. The implementation of this change in punch rate eliminated the need for the two divide-by-10 cards that had formerly been used to reduce the 1-kc timing frequency to 10 cps. Also, since the input timing-signals for TIROS II were already approximately 1-kc, the need for the divide-by-3 card that had been used for converting the 3-kc input signal of TIROS I into the 1-kc timing frequency was eliminated. Instead, this card was used to convert the 60-cps line frequency to the 20-cps signal required for the new punch rate.

The automatic starting and stopping capability was incorporated by changing the input connections to the two existing start/stop flip-flops. A start/stop input connector was provided so that successive input pulses would alternately set and reset the flip-flops. The existing manual start/stop switch was replaced by a three-position, center-off switch. Finally, an additional connection was made to one of the flip-flops to allow the sense input signal to also be gated on and off.

c. Functional Description

The logic diagram for the DTMD is shown in Figure 67.§ The DTMD receives as its input either the I-4 data output of the IR buffer, or the attitude-, timing-, and sense-pulse outputs of the attitude pulse selector. When the DTMD is being used to reduce horizon-sensor data (receiving its input from the attitude-pulse selector), a 1-kc master timing input must also be applied to the unit. When the unit is being used to reduce the I-4 data, the 1030-cps channel of the I-4 data serves as the master timing signal.

The input pulses to the DTMD trigger its counters sequentially. Each counter is scanned and its contents are punched out on paper tape through use of a Friden tape punch. The readout-time for the tape punch is in the order of 0.3 seconds. Since it is possible to receive more than one input during this 0.3-second period, logic is provided so that the information content of any counter may be stored until the punch has completed the preceding scan. This is accomplished through the use of three sets of counters, which are sequentially gated on by the input pulses. Scanning of the counters is also done sequentially. Logic circuits are provided which prevent a second counter from being scanned until the scan of the preceding counter has been completed.

§ This illustration is printed on a foldout page located at the rear of this Section.

Counting is accomplished by gating the 1-kc master timing signal, or the 1030-cps channel of the I-4 data, into the appropriate counters. Each time that a data input pulse is received, the counter which had been in use is turned off and the master timing signals are applied to the next counter in the sequence. Thus the count stored within a counter, and hence the count which is read out, is the time interval between two successive inputs.

If an input is not received during a ten-second interval, an internal pulse is generated which causes the punch to read out four zeros. This readout indicates that a 10-second interval has passed and, at the same time, shifts the timing input to the next counter. Use of the technique permits real time to be accumulated on the paper tape. When data inputs are received at a 1-pps rate, the output of the tape punch is one-second intervals punched on paper tape. This output is in the form of standard, 5-line, Baudot teletype code.

The output format is such that four digits are printed, indicating time between pulses in milliseconds, followed by a space if the last pulse to enter the DTMD was either a timing pulse or an earth-sky transition, and a comma if the last pulse was a sky-earth transition. The sense output from the attitude pulse selector provides this information. Every tenth reading is followed by "carriage return," "line feed," and "figures" for purposes of readout by a teleprinter.

Provision is made for preserving real time in the event that more than two pulse inputs occur during the time required for a scan. In this instance all inputs are inhibited until the counters have been cleared sufficiently to accept one of the imprints.

A detailed description of circuit logic is presented in "Instruction and Operating Handbook, TIROS II Meteorological Satellite System" (Reference 4).

H. TAPE RECORDERS

In order to provide for the recording of the composite IR signal, the IR events signal (channel 4 IR), the 16.5-kc IR timing signal, and the summed AGC voltages of the IR receivers, it was necessary to increase the capacity of the Ampex recorders to 7 channels. Since the TIROS I tape recorders were mounted in short, front accessibility racks, it was necessary to install the additional tape-recorder electronics in a separate rack. The following are the channel assignments for the two TIROS II tape recorders:

Recorder	Tape Recorder	
Channel	1	2
1	Video Subcarrier	Video Subcarrier
2	Index Number	Index Number
3	Raw Sun Angle Data	Computed Sun Angle
4	Composite IR	Composite IR
5	IR Events Signal	IR Events Signal
6	16.5-kc IR Signal	16.5-kc IR Signal
7	Summed TV AGC	Summed TV AGC

A discussion of the reasons for selecting the Ampex recorders for use in the TIROS Meteorological Satellite System is included to the TIROS I Final Report (Reference 1).

I. EVENTS RECORDER

1. General

A 20-channel Esterline-Angus events recorder (Model AW) was installed in each of the TIROS II CDA stations. The recorders, which were government-furnished equipment (residual from TIROS I), provided on-off indications versus time on a paper chart. These on-off indications provided a direct, real-time record of the set-up of the command program for use in checking equipment malfunctions or operator failures prior to a pass, and also provided a permanent record of the commands sent during an actual pass.

The recorder was equipped with both manual and automatic start features. Manual start was used during station troubleshooting and maintenance operations. Automatic start was used for normal operation of the equipment.

2. Functional Description

In automatic start, the chart is set under the pens to a one-minute interval mark. When alarm 1 is received by the command programmer, a start signal is applied to the recorder and starts the chart in motion. Real-time start of the chart is, therefore, the alarm 1 time of the particular pass. This real-time, along with a rubber stamped indication of various other functions such as orbit number, is placed on the recording chart for permanent identification. The 20-channel events recorder provided on-off indications for the following components and program sequences:

RECORDER CHANNEL	FUNCTION RECORDED	
1	Direct Camera 1	Program A
2	Direct Camera 2	
3	Playback Camera 1	
4	Playback Camera 2	
5	Set Clocks	
6	Start Clocks	
7	IR Start	
8	IPP 10 seconds	
9	Direct Camera 1	Program B
10	Direct Camera 2	
11	Playback Camera 1	

RECORDER CHANNEL	FUNCTION RECORDED
12	Playback Camera 2
13	Set Clocks
14	Start Clocks
15	Attitude Control
16	Camera Shutter
17	TV Receiver 1
18	TV Receiver 2
19	IR Receiver 1
20	IR Receiver 2

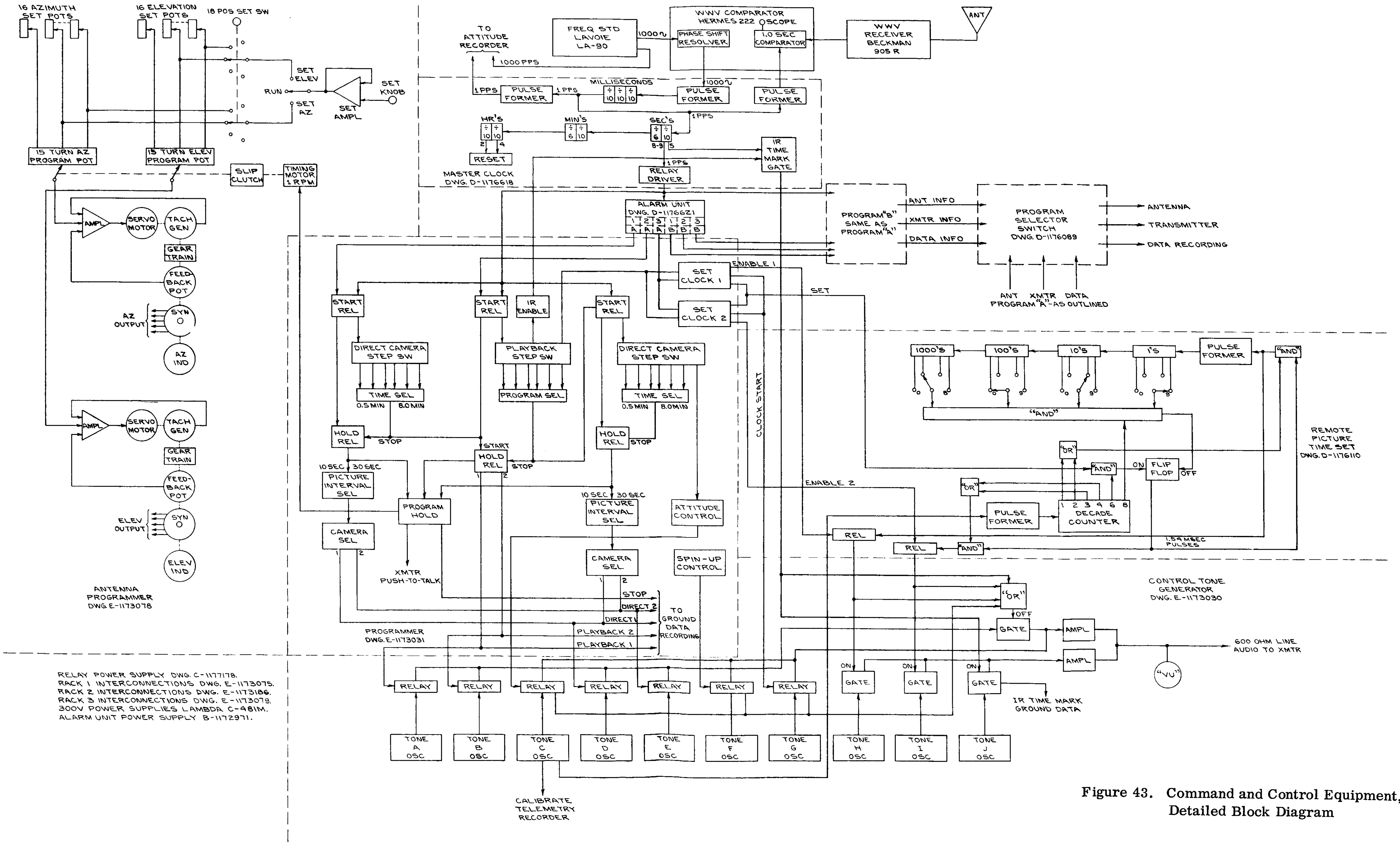


Figure 43. Command and Control Equipment, Detailed Block Diagram

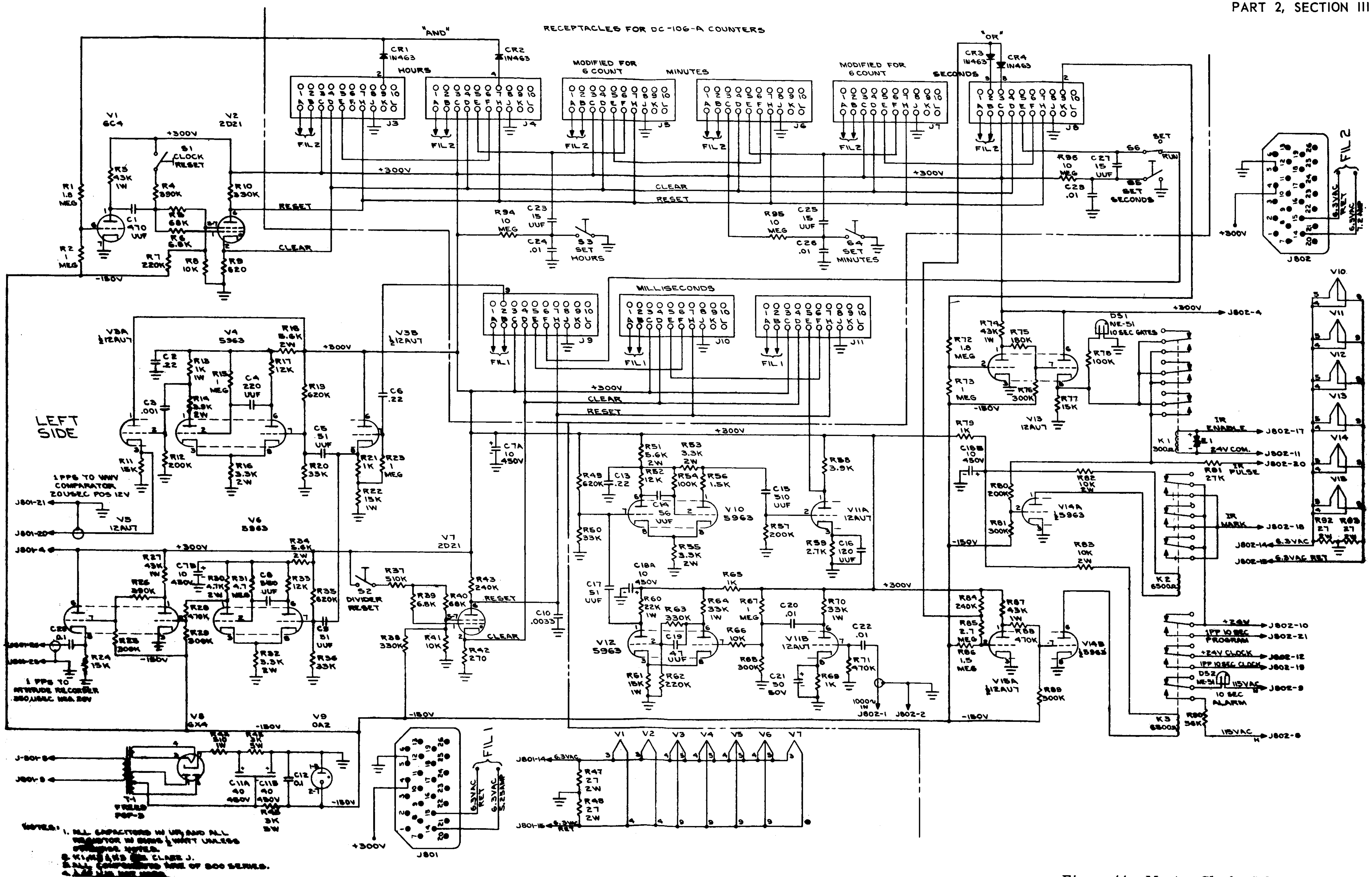


Figure 44. Master Clock, Schematic Diagram

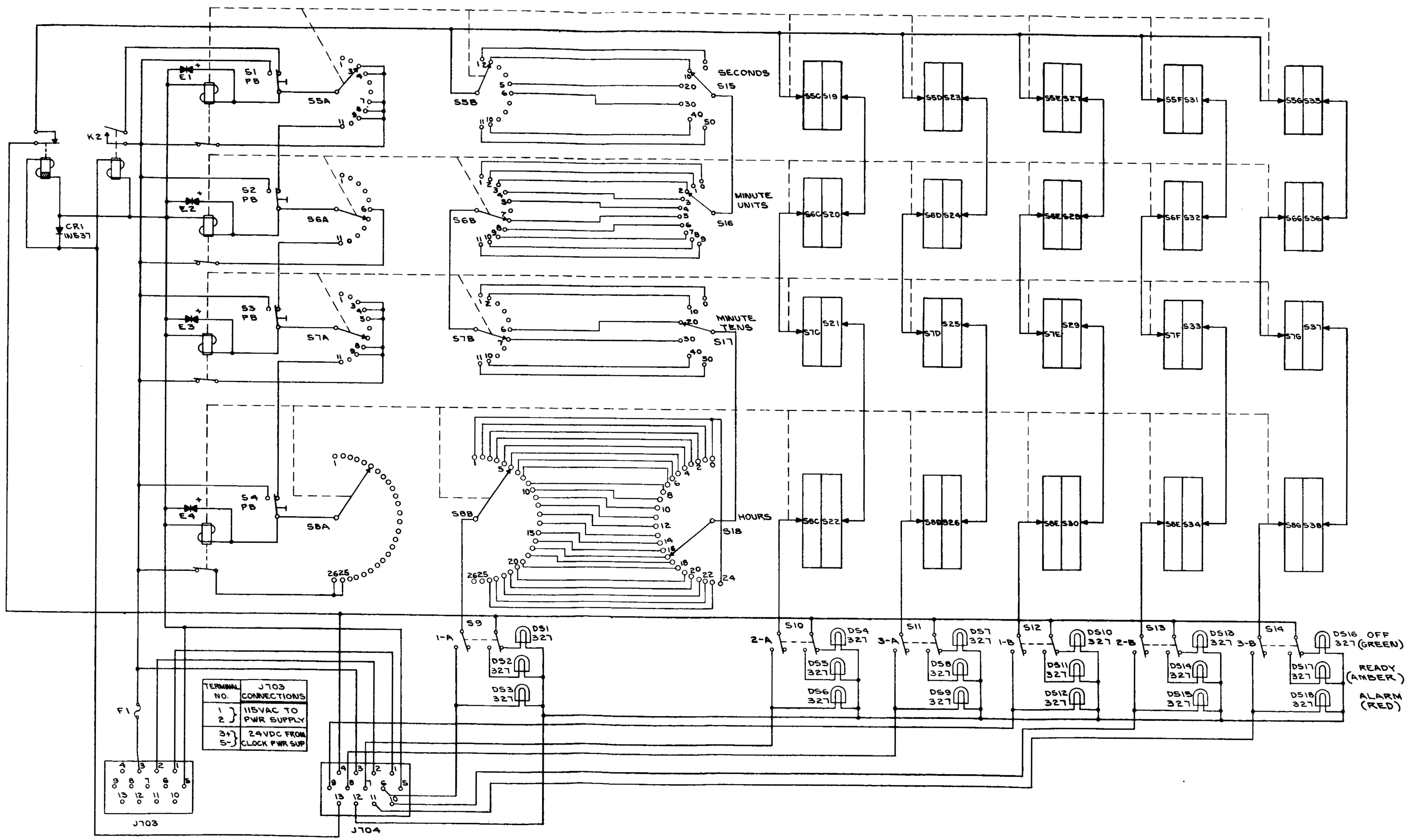


Figure 45. Master Clock Alarm Unit, Schematic Diagram

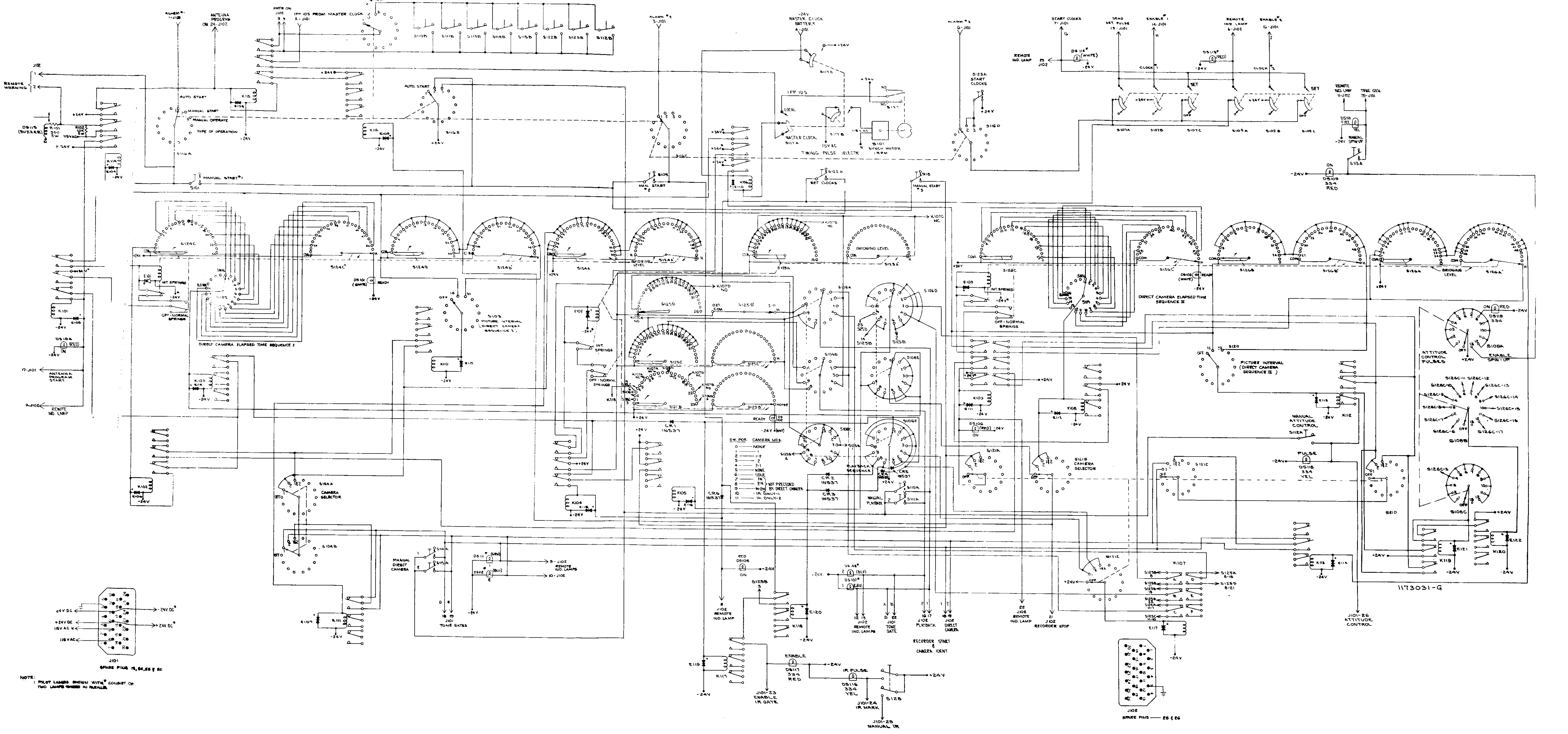
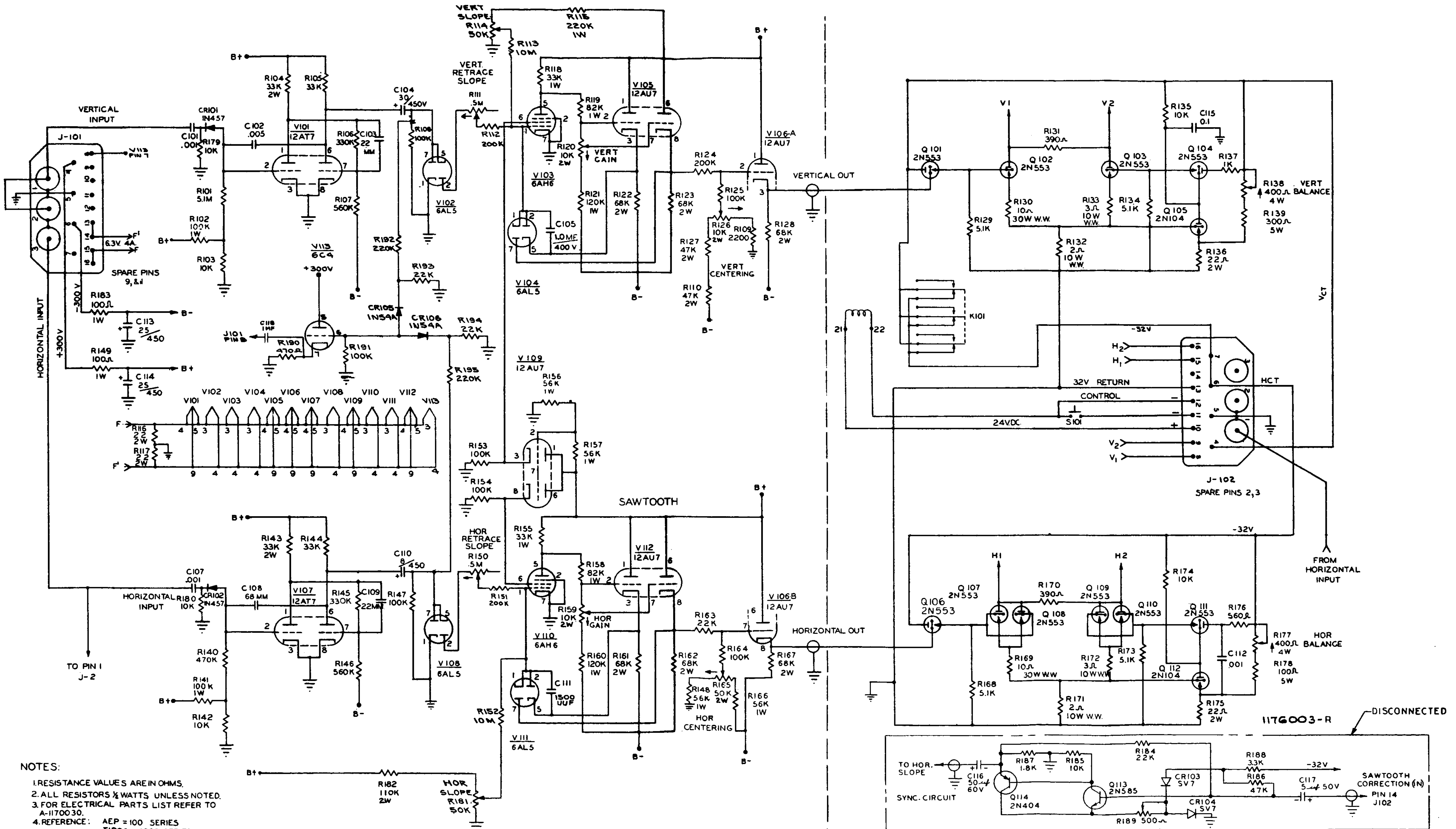


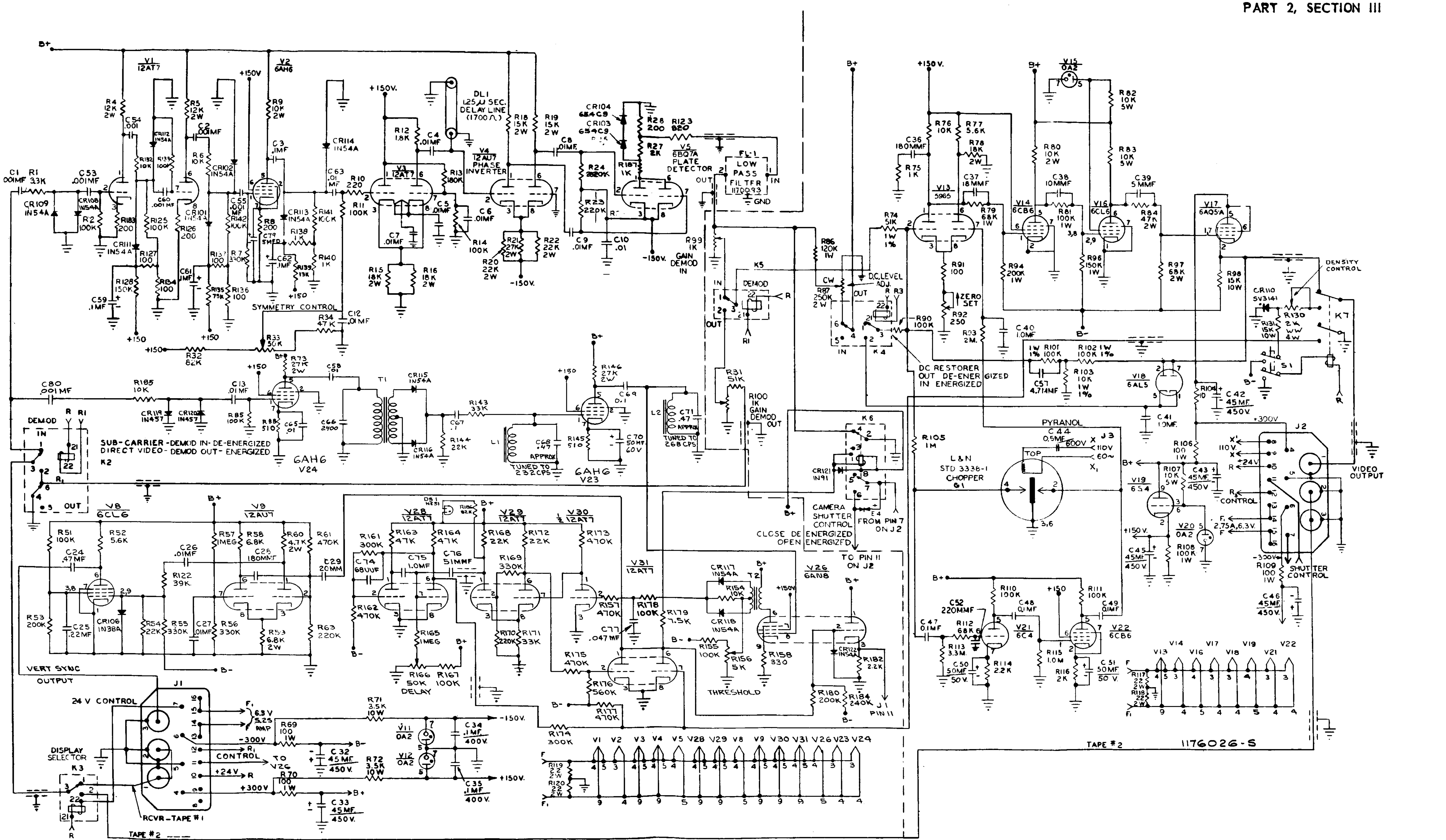
Figure 46. Command Programmer, Schematic Diagram



NOTES:

1. RESISTANCE VALUES ARE IN OHMS.
2. ALL RESISTORS ½ WATTS UNLESS NOTED.
3. FOR ELECTRICAL PARTS LIST REFER TO A-1170030.
4. REFERENCE: AEP = 100 SERIES TIROS = 4200 SERIES
5. ALL CAPACITORS ARE MF UNLESS NOTED

Figure 54. Sawtooth and Deflection Amplifier, Schematic Diagram



NOTES:
1. ALL RESISTORS VALUES ARE IN OHMS AND ½ WATT UNLESS NOTED.
2. FOR LIST OF MATERIALS REFER TO DWG 1170094.
3. RELAYS SHOWN IN DE-ENERGIZED POSITION

NOTES:
4 REFERENCE: AEP = 500 SERIES
TIROS = 4400 SERIES

Figure 56. TV-FM Demodulator, Schematic Diagram

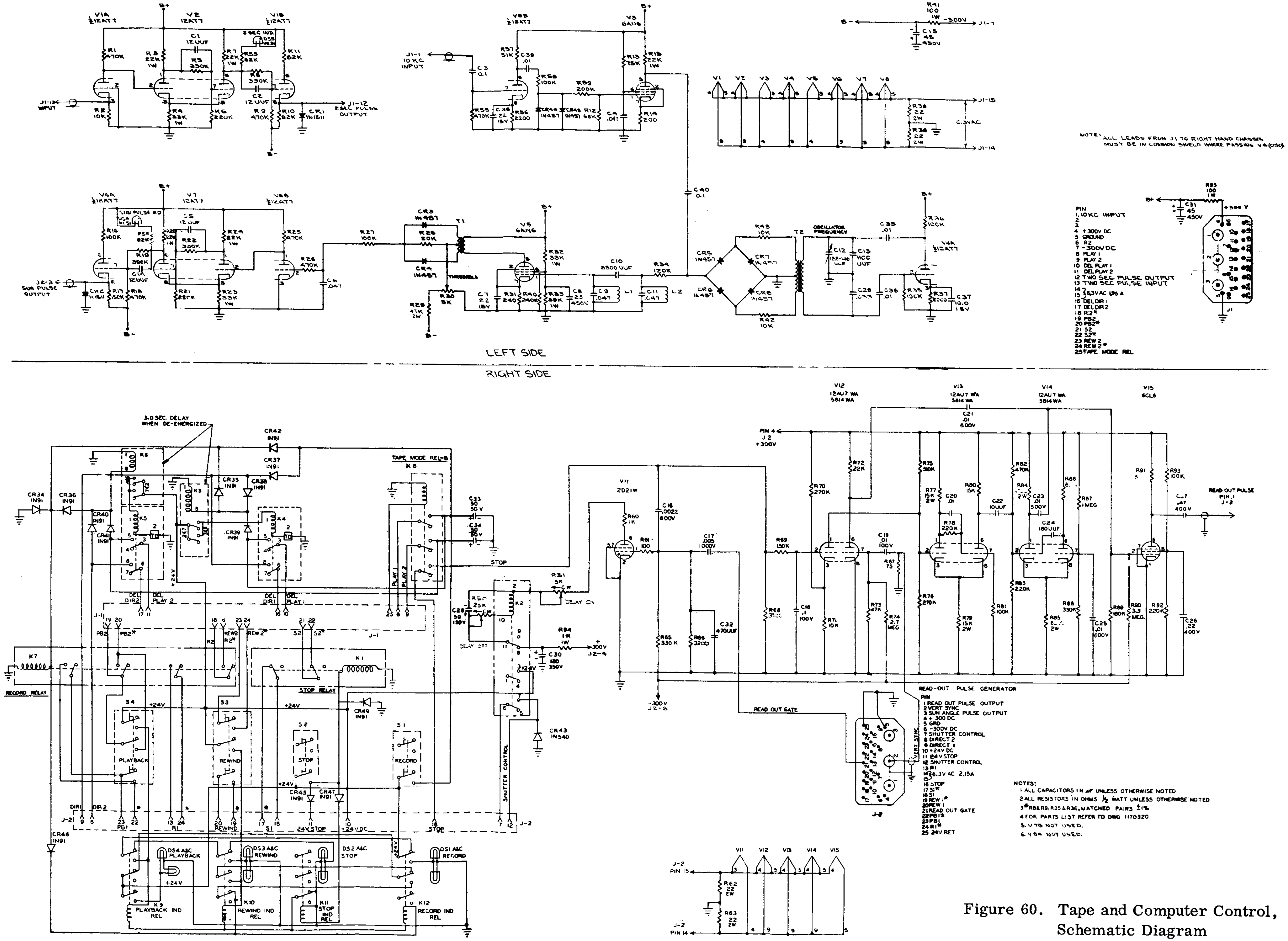


Figure 60. Tape and Computer Control, Schematic Diagram

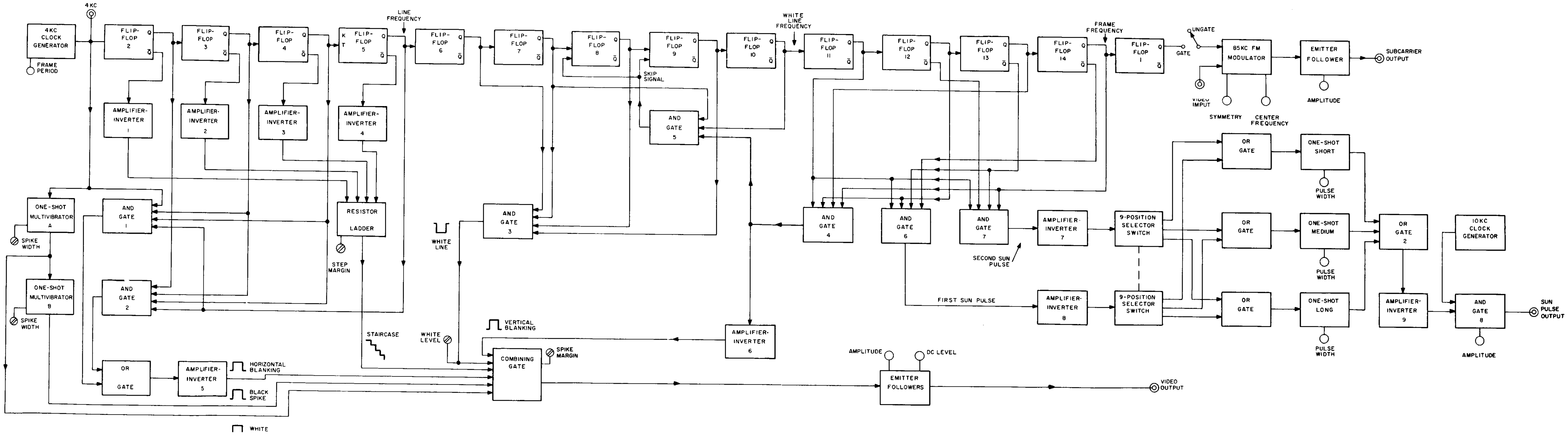


Figure 62. Calibrator, Schematic Diagram

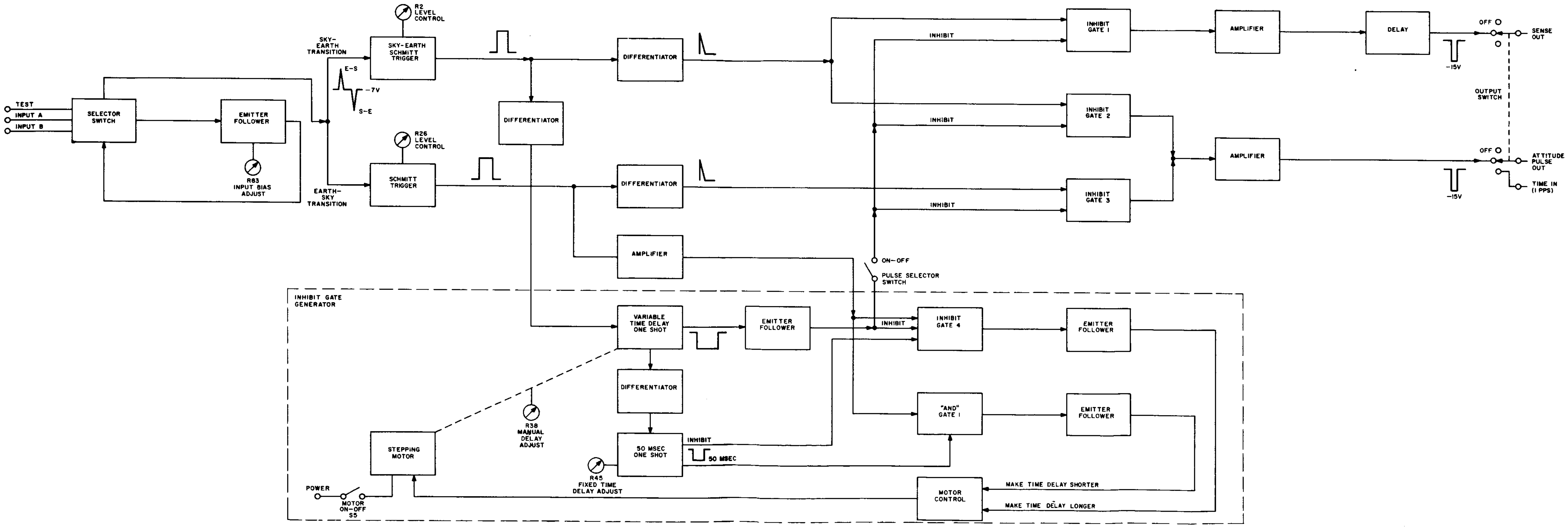
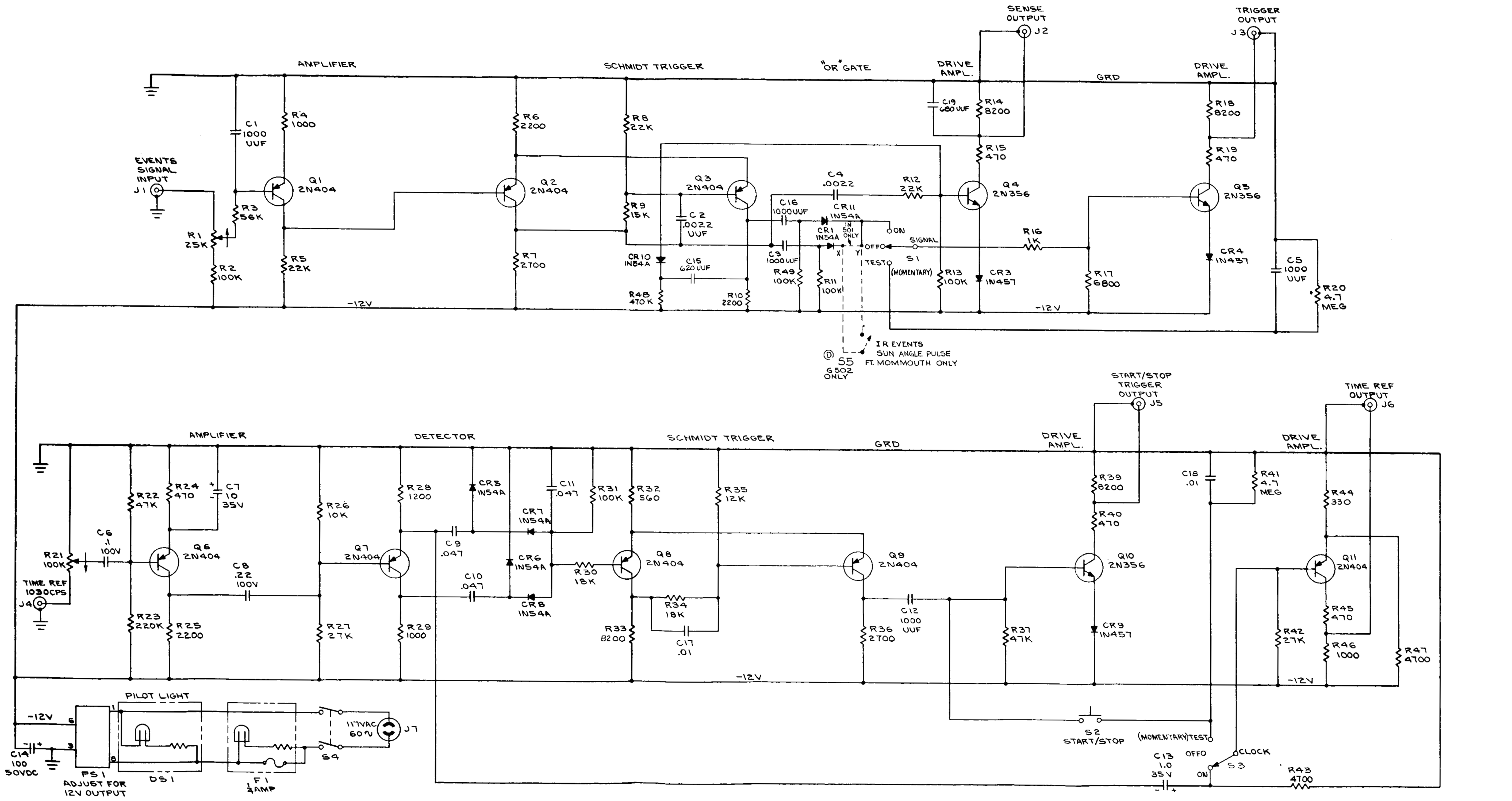


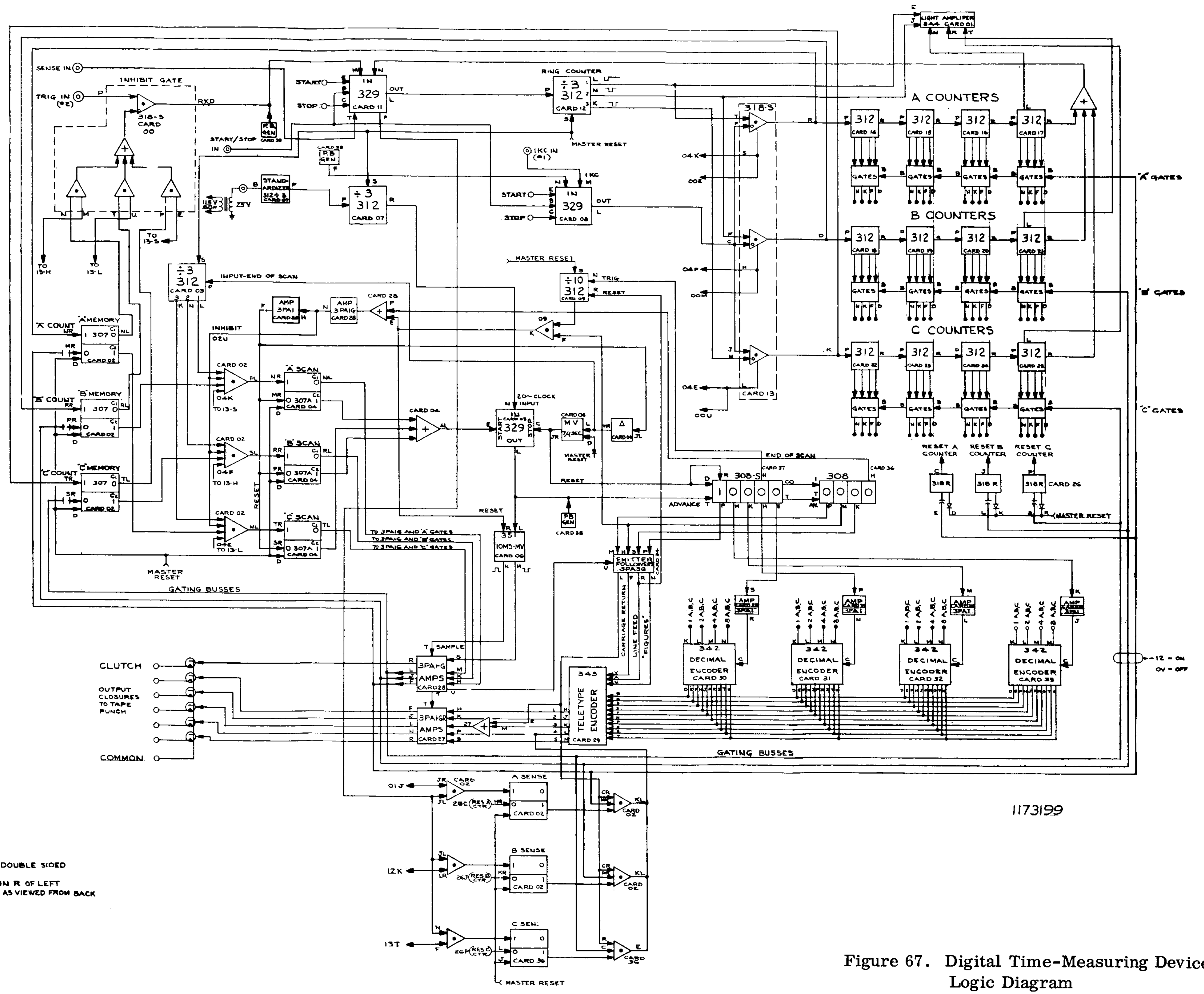
Figure 63. Attitude Pulse Selector, Block Diagram



SYMOLS	C	CR	DS	F	J	PS	Q	R	S
LAST USED	19	11	1	1	7	1	11	49	5
OMITTED		2						38	

NOTE: ALL CAPACITORS IN UUF, AND ALL RESISTORS IN OHMS ½W UNLESS OTHERWISE NOTED.

Figure 66. IR Buffer, Schematic Diagram



NOTE
307'S UTILIZE DOUBLE SIDED CONNECTOR.
RL DENOTES PIN R OF LEFT COLUMN OF PINS AS VIEWED FROM BACK

Figure 67. Digital Time-Measuring Device, Logic Diagram

SECTION IV. SATELLITE CHECKOUT EQUIPMENT

A. INTRODUCTION

The checkout equipment, commonly called the Go, No-Go equipment, was essentially a ground station, with limited operational capabilities, used for checking out the TIROS satellites. This equipment, which was originally developed for TIROS I and then modified for use in the TIROS II project, was first utilized at Princeton for qualification testing of of the TIROS satellites. It was then transferred to the launch site at Cape Canaveral for operational checkout of the satellites during pre-launch and launch operations. Operational checks were made on the satellites at a pre-launch facility in Hangar AA, the spin-balance building in Area 5, and Launch Pad 17A. Checkout at Hangar AA was performed via coaxial cable connections between the satellite and the Go, No-Go van. Checks made from Hangar AA, while the satellite was either in the Area 5 spin-balance building or on Launch Pad 17A, were performed via transmitting and receiving antennas.

B. DEVELOPMENT AND DESIGN

The preliminary design considerations and the initial design efforts involved in development of the Go, No-Go equipment are described in Volume II of the TIROS I Final Report (Reference 1). The discussion here is limited to modifications and additions made to the equipment in preparing it for use in the TIROS II project. The purpose of these modifications and additions was:

(1) To improve equipment performance; and

(2) To accommodate the IR and attitude control functions which were included in the TIROS II satellite.

The major modification made on the Go, No-Go equipment was the revision of the TV receiving circuits. The TV system used in the TIROS I checkout equipment was developed for checking out the TIROS TV system during the earlier phases of TV-system development. Because of this, the Go, No-Go system lacked later refinements and therefore provided what was primarily a quantitative check of the TV picture subsystem, with limited regard to picture quality.

After launch of TIROS I, an evaluation of the checkout program indicated the desirability of obtaining TV pictures which could be compared more favorably with the pictures recorded at the CDA stations. Accordingly, the TV receiving system for the TIROS II Go, No-Go equipment was made very similar to the TV receiving systems of the CDA stations.

The primary difference was that the Go, No-Go system did not use polarization diversity combination.[1]

A second modification to the Go, No-Go equipment involved the command programmer. The TIROS I programmer, being of very simple design, permitted only one satellite clock to be set at a time. Since the orbiting satellite's clocks were often set simultaneously, it was considered advisable that the TIROS II Go, No-Go be capable of sending "clock-set" pulses to both clocks at the same time. This modification was implemented by replacing the programmer's tone selector switch with an individual pushbutton control (and related circuitry) for each of the satellite-command tones. Inclusion of this capability permitted the satellite clocks to be set using programming which more closely paralleled actual satellite programs.

The modification to the programmer also involved the addition of two new command tones; one for commanding IR end-of-tape, and the other for activating the satellite's attitude control.

A third modification to the Go, No-Go equipment was necessitated by inclusion of the IR function in the satellite. This modification eliminated one of the two 108-Mc antennas and added, in its place, a 240-Mc antenna for reception of the IR signal. (Elimination of the 108-Mc antenna provided a mounting area for the IR antenna.) An analysis showed that the use of only one 108-Mc antenna system would result in a 3-db decrease in level of telemetry signals; however, this loss in level was considered acceptable since the level of the telemetry signal received during TIROS I checkout proved to be more than adequate.

Modifications to the Go, No-Go equipment also included the addition of an Esterline-Angus events recorder and a second Nems-Clarke Model 1411 receiver. The Nems-Clarke receiver was added to provide amplification of the IR carrier. The events recorder was included as part of the TIROS II Go, No-Go equipment to provide a permanent record of each satellite checkout program.

C. FUNCTIONAL DESCRIPTION

The operation of the Go, No-Go checkout equipment is divided into two phases; namely, the command transmitting phase, which consists of programming the satellite for its various modes of operation, and the receiving phase which consists of displaying the satellite's TV pictures on a kinescope, and of receiving and recording the IR and telemetry data. Figure 68[§] is a block diagram of the TIROS II Go, No-Go checkout equipment.

The satellite command signals consist of an RF carrier modulated by radio frequency tones. Satellite programming is accomplished by means of a manually controlled programmer. The audio tone, related to a desired command, is initiated by depressing the related "tone" pushbutton on the programmer front panel. The selected tone-output of the programmer is

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[1] Polarization diversity combination was employed at the CDA stations to minimize signal fading caused by the orbital spin rate of the satellite.

§ This illustration is printed on a foldout page located at the rear of this Section.

applied to the command transmitter where it modulates the carrier signal. The carrier signal, whose frequency is crystal controlled, has a maximum power level of 3 watts.

The Go, No-Go programmer provides for commanding the satellite to:

(1) take pictures and transmit them directly to the ground station;

(2) set and then start the clocks for remote picture taking sequences;

(3) playback pictures which were taken during a remote sequence and then stored in the satellite's tape recorders;

(4) control the satellite's attitude;

(5) start playback of IR data; and

(6) fire selected pairs of spin-up rockets.

The receiving phase of Go, No-Go equipment operation is divided into three parts: telemetry reception, TV reception, and IR reception. The telemetry information is received on two carriers (108.00 and 108.03 Mc), which are converted to 14.40 and 14.43 Mc, respectively. Separate receivers, fed by the same antenna and frequency converter, amplify and demodulate the 14.40 and 14.43 Mc signals. After demodulation, the telemetry data, in the form of a 1.3-kc $\pm$ 0.1-kc FM subcarrier, is recorded on a two-channel Sanborn chart recorder.

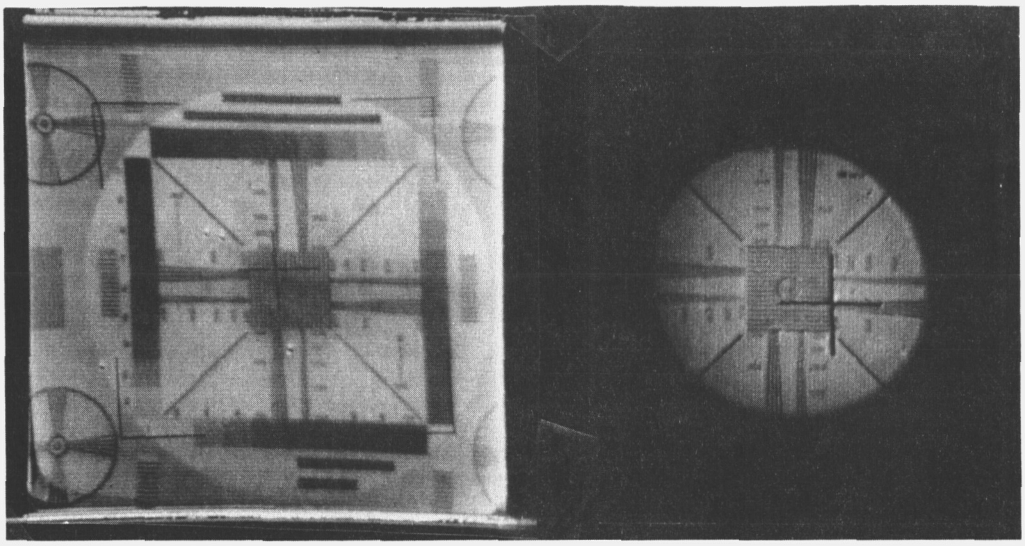
The video signal, an 85-kc $\pm$ 15-kc FM subcarrier with modulation frequencies between 0 and 62.5 kc, is transmitted from the satellite on a 235-Mc carrier. The 235-Mc carrier is received via a 10-element Yagi antenna, amplified, and demodulated to obtain the 0 to 62.5-kc video signal. The picture that results from the video signal is displayed on a kinescope which is synchronized by the horizontal and vertical sync components of the signal. Photographs of the kinescope display are taken using a Polaroid camera. Typical photographs are shown in Figure 69.

Detailed operation of the Go, No-Go TV circuits is essentially the same as the operation of the TV systems in the CDA stations; the primary difference is that the Go, No-Go system does not employ polarization diversity combination. The IR data is also received by a 10 element Yagi antenna. The IR data and its 237.8-Mc carrier is amplified by a Nems-Clarke Model 1411 receiver. The output of the receiver is applied to NASA operated IR checkout equipment for evaluation.

D. OPERATIONAL CHECKS OF THE TIROS I SATELLITE AT THE LAUNCH SITE

The following Go, No-Go checks were made to determine whether or not the satellite was functioning correctly.

Command checks were made to determine the response made by the satellite to each command and to determine the time delay between the command and the response.



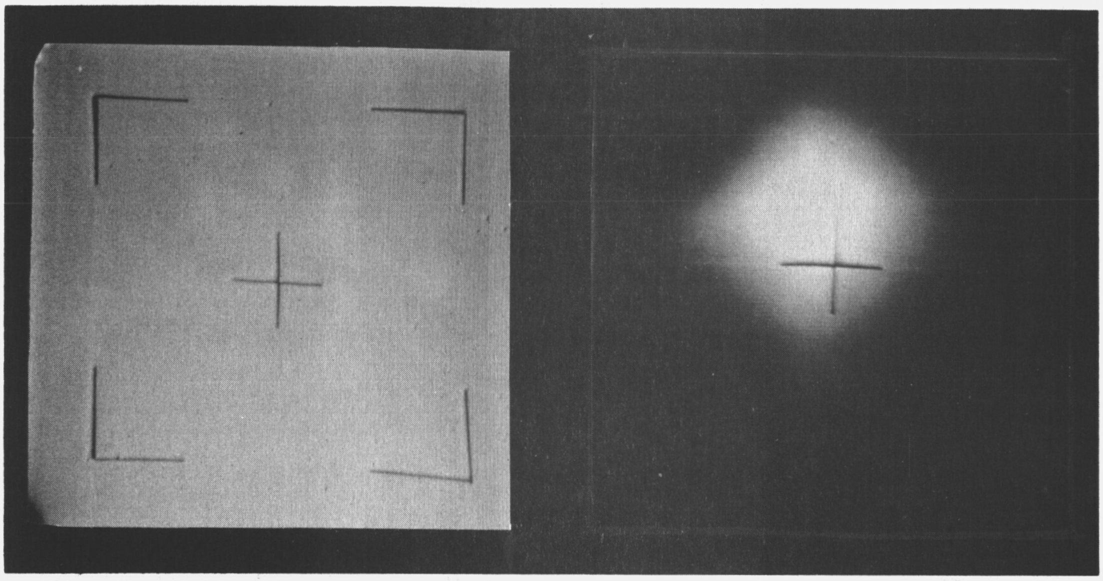
NARROW ANGLE CAMERA WIDE ANGLE CAMERA

Figure 69. Satellite Checkout Equipment, Typical TV Subsystem Test Photographs of Test Pattern

Telemetry checks were made by placing standard overlays over the recorded telemetry data. The overlay was marked off with tolerance limits for each of the 39 telemetry channels.

Video checks were made to determine whether or not the operation of the satellite cameras and tape recorders was satisfactory. A camera target was supplied by a collimated light, with an appropriate lens system, for the initial evaluation. This operation was performed before the satellite's protective shroud was put in place. After the protective shroud was in place, a light source of 1000 foot-lamberts was diffused directly into both camera lens. Photographs of the video display were made using a Polaroid camera; typical photographs are shown in Figure 70.

The nine north-indicator signals were transmitted from the satellite on the 235-Mc TV carrier in the form of 10-kc tone bursts. The north indicators were activated during check-out by means of a high-intensity light. The output from the 235-Mc receiver was displayed on an oscilloscope, and photographs of the 10-kc tone burst from each indicator were taken with a Polaroid camera. A typical set of photographs is shown in Figure 71.



NARROW ANGLE CAMERA WIDE ANGLE CAMERA

Figure 70. Satellite Checkout Equipment, Typical TV Subsystem Test Photographs

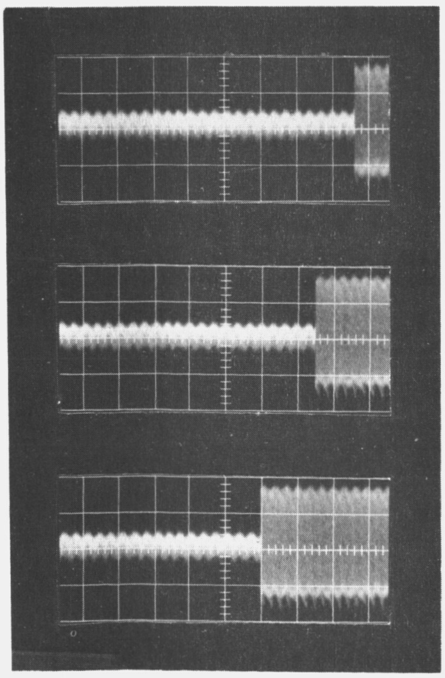


Figure 71. Satellite Checkout Equipment, Typical Test Photographs of North-Indication Signals

The horizon scanner signal was transmitted on both 108-Mc telemetry carriers and displayed on the Sanborn recorder. The horizon scanner was activated by a high intensity light during checkout.

The satellite-borne attitude control switch was stepped to each of its various positions by means of a command tone from the Go, No-Go equipment. The operation of the switch was checked by making a voltage reading across the attitude coil while the switch was in each of its positions. Since each position of the attitude control switch results in a specific modulation of the telemetry subcarrier, the switch position could be determined by interpretation of the data recorded of the Sanborn chart recorder.

Checkout of the IR equipment was, for the most part, accomplished by NASA representatives using government furnished equipment. The Go, No-Go equipment was used only for sending the IR end-of-tape pulse and the playback command for the IR tape recorder, and for receiving the IR carrier.

E. CHECKS MADE ON THE GO, NO-GO EQUIPMENT

Performance checks were made on the checkout equipment prior to each interrogation of the satellite. Each performance check included the monitoring of the following: (1) the voltage and current levels of the main power source and the individual power supplies; (2) the output frequency, and percent modulation of the command transmitter, and (3) the command frequencies and "clock-set" pulse outputs of the programmer. In addition to the performance checks, calibration runs were made on the Sanborn recorder and the TV system prior to each use of the checkout equipment.

F. ANTENNAS AND RF PROPAGATION

Four ten-element Yagi antennas (one for the 108-Mc band, one for the 140-Mc band, and two for the 240-Mc band) were employed in the TIROS II checkout equipment. These antennas had gains of approximately 10db. The 140-Mc band transmitting antenna was vertically polarized to accommodate the satellite's receiving antenna which was also vertically polarized when the satellite was in its launch position. The three receiving antennas were horizontally polarized. This choice of polarization was made after tests showed that, with the satellite in the launch position, horizontally polarized receiving antennas provided better reception of the circularly polarized satellite transmissions than did vertically polarized antennas.

Go, No-Go checks were made via RF links both while the satellite was on the launch pad and while it was in the spin-balance facility. Although the spin-balance building was approximately ten degrees out of the line-of-sight between Hangar AA (location of Go, No-Go equipment) and the launch pad, the beam width of the antennas was sufficiently wide to permit tests to be run at either location without repositioning the Go, No-Go antennas. However, since the spin-balance facility was a steel structure and was located behind a mound, it was necessary to provide external dipoles for the satellite's transmitting and receiving antennas whenever tests were made at that facility. These external dipoles were mounted outside the building at a higher elevation than the mound.

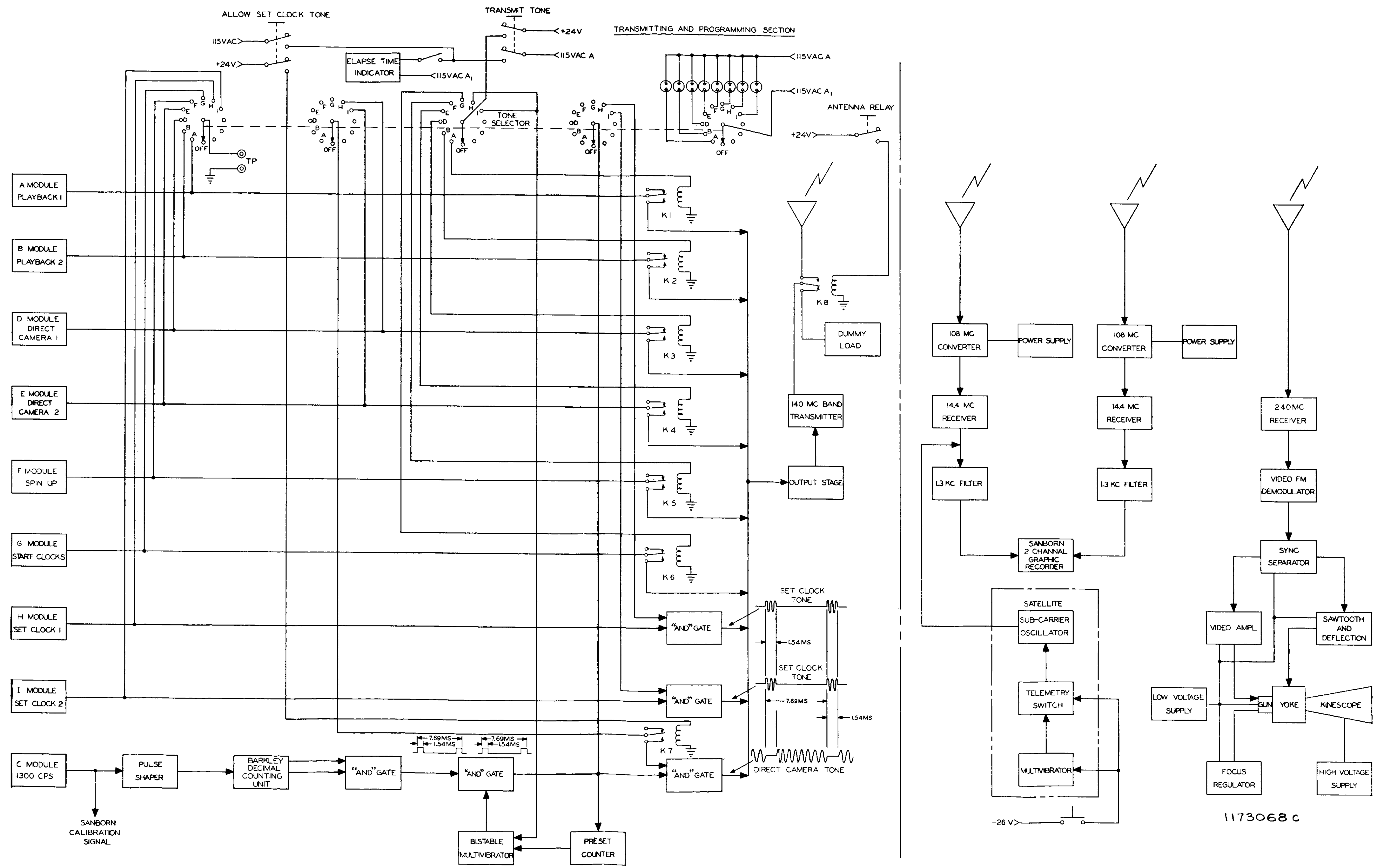


Figure 68. Checkout (Go, No-Go) Equipment Block Diagram